International Correspondence Schools
Scranton, Pa.

Inorganic Chemistry

Chemical Calculations — Colloids
Electron Theory — Periodic Law

PREPARED ESPECIALLY FOR HOME STUDY

BY

HUGH E. DeFAZIO, B.S.
PRINCIPAL, SCHOOL OF CHEMISTRY

IN COLLABORATION WITH

MORRIS LAWRENCE, Ch.E.
DIRECTOR, SCHOOL OF CHEMISTRY

5560C — PART 3 — EDITION 1

Copyright, 1944, by International Textbook Company. Copyright in Great Britain. All rights reserved

5560C

Printed in U. S. A.

1944 Edition

INORGANIC CHEMISTRY

Serial 5560C (PART 3) Edition 1

CHEMICAL CALCULATIONS

PROPORTION, PERCENTAGE, AND CALCULATIONS OF QUANTITIES

INTRODUCTION

1. The industrial chemist must be able to solve chemical problems, since they enter into all laboratory and industrial operations. To him, the chemical equation is of greatest importance. By means of it, he can determine the per cent and quantity of a constituent in a material, how much material he actually needs for a given reaction, and what amount of product may be produced. However, the full amount of product, as calculated from the equation, is very seldom obtained. The chemist can, therefore, determine the efficiency of the industrial process; that is, what percentage of the theoretical yield, as computed from the equation, is actually obtained. These computations are all based on the chemical equations of the reactions and, unless the chemist knows how to solve chemical problems with accuracy, his efforts will be of little value. It is, therefore, important that the methods of solving problems described at this point should be carefully studied and thoroughly understood.

PROPORTION

2. Fundamental Principles.—The mathematics involved in the solution of chemical problems consists essentially of the principles of proportion. A proportion is an equality of ratios, the equality being indicated by the sign (=). Thus, to write

COPYRIGHTED BY INTERNATIONAL TEXTBOOK COMPANY. ALL RIGHTS RESERVED

(7) A gas occupies a volume of 750 milliliters at a temperature of 20° C. and a pressure of 790 millimeters. What volume will it occupy under standard conditions of temperature and pressure? Ans. 726.389 ml.

(8) Calculate the per cent of MgO in magnesium pyrophosphate, $Mg_2P_2O_7$. Ans. 36.22%

(9) When calcium carbonate is heated to about 825° C., the following reaction takes place:

$$CaCO_3 \rightarrow CaO + CO_2$$

How many tons of quicklime, CaO, may be produced by heating 5 tons of calcium carbonate? Ans. 2.801 tons.

(10) State the number and location of the protons, neutrons, and electrons in the atom of the following elements: helium, nitrogen, neon, sulfur, and calcium.

(11) (*a*) State Moseley's periodic law. (*b*) What is the weight of 1 liter of hydrogen at standard conditions of temperature and pressure?

(12) How many milliliters would 10 kilograms of concentrated sulfuric acid occupy if it had a specific gravity of 1.84? Ans. 5,434.78 ml.

(13) A compound has a molecular weight of 142.054 and the following percentage composition: sodium, 32.38%; sulfur, 22.57%; and oxygen, 45.05%. What is the formula for the compound?

(14) (*a*) State two methods for preparing a colloid? (*b*) Give an example of each method.

(15) What weight of H_2S gas (approximate density 17) occupies a volume of 100 liters at 30° C. and 750 millimeters of pressure? Ans. 135.841 g.

Mail your work on this lesson as soon as you have finished it and looked it over carefully. DO NOT HOLD IT until another lesson is ready.

given, and also the first term, 30, of the second ratio, which term is the third term of the proportion, and one of the means. The unknown term in a proportion is usually indicated by the letter x. The given ratios may therefore be written as the following proportion:

$$6 : 13 = 30 : x$$

The unknown extreme x may be found by the following rule:

Rule.—*To find an unknown extreme, divide the product of the means by the given extreme.*

Applying this rule to the preceding example

$$x = \frac{13 \times 30}{6} = \frac{390}{6} = 65$$

7. If the unknown term is one of the means, the following rule applies:

Rule. *To find an unknown mean, divide the product of the extremes by the given mean.*

EXAMPLE.—The two ratios 17 : 51 and x : 42 are given. What is the value of the unknown term x?

SOLUTION.—In this example, the terms 17 and 42 are the extremes, and 51 the given mean. Applying the rule,

$$x = \frac{17 \times 42}{51} = \frac{714}{51} = 14. \quad \text{Ans.}$$

8. In certain branches of chemical calculations a proportion is perferably stated in the form of a ratio, as $\frac{3}{9} = \frac{x}{36}$, x being the unknown quantity, as before. Applying the method explained in Art. 5, the following equation is obtained: $3 \times 36 = 9 \times x$. In order that the unknown quantity x may stand alone on one side of the equality sign, both sides of the equation are divided by 9. Thus, $\frac{3 \times 36}{9} = \frac{9x}{9}$.

Or, $$x = \frac{3 \times 36}{9} = 12$$

PERCENTAGE CALCULATIONS

9. Advantage of Percentage Calculations.—In certain operations pertaining to chemistry, it is very convenient to consider the quantity under consideration as being divided into 100 equal parts. Thus, instead of using the ordinary fractions $\frac{1}{4}$, $\frac{2}{5}$, and $\frac{2}{7}$, the equivalent fractions $\frac{25}{100}$, $\frac{40}{100}$, and $\frac{28\frac{4}{7}}{100}$ are used, or their equivalent decimals, .25, .40, and .286, respectively. The reason for this is that it is much easier to work with fractions whose denominators are 100 than it is to work with fractions whose denominators are composed of other figures.

10. Definition.—*Percentage* is a term applied to those arithmetical operations in which the number or quantity concerned is divided into 100 equal parts.

The term *per cent* means *by the hundred*. Thus, 8 per cent of a number means 8 hundredths, that is, $\frac{8}{100}$, or .08, of that number; 8 per cent of 250 is $250 \times \frac{8}{100}$, or $250 \times .08 = 20$; 47 per cent of 75 ounces is $75 \times \frac{47}{100} = 75 \times .47 = 35.25$ ounces.

The sign of the per cent is %, and is read "per cent." Thus, 6% is read "six per cent;" $12\frac{1}{2}$% is read "twelve and one-half per cent," etc.

When expressing the per cent of a number used in calculations, it is customary to express it decimally instead of fractionally. Thus, instead of expressing 6%, 25%, and 43% as $\frac{6}{100}$, $\frac{25}{100}$, and $\frac{43}{100}$, it is usual to express them as .06, .25, and .43, respectively.

11. Use of Atomic Weights in Problems.—Atomic weights are used to calculate the relative quantities, called combining weights, in which elements enter into compounds and in which substances enter into chemical changes. All chemical problems are based on the law of definite proportions, which states, as mentioned in a previous lesson, that a chemical compound always contains the same constituents in the same proportion by weight.

Consider, for example, water, the formula of which is H_2O. This formula shows that each molecule of water contains 2 atoms of hydrogen and 1 atom of oxygen. This fact is always true for water. By means of the atomic weights of these elements, one can calculate the weight relation between oxygen and hydrogen in water. The atomic weight of hydrogen, as shown in Table I, is 1.008, and that of oxygen is 16. The molecular weight of water is $(2\times1.008)+16$, or 18.016. These values show that every 18.016 parts* of water contain 2.016 parts of hydrogen and 16 parts of oxygen. That is, the weight ratio of hydrogen to oxygen, in water, is 2.016 : 16, and 2.016 parts of hydrogen are needed to combine chemically with 16 parts of oxygen to produce 18.016 parts of water.

These parts by weight can be expressed in terms of any weight unit, such as grams, pounds, tons, kilograms, etc. For instance, when grams are used every 18.016 grams of water contain 2.016 grams of hydrogen and 16 grams of oxygen; 2.016 grams of hydrogen unite with 16 grams of oxygen to produce 18.016 grams of water, and the ratio of hydrogen to oxygen in 18.016 grams of water is 2.016 grams : 16 grams.

These various weight relations based on the atomic weights of elements are used in the solution of chemical problems.

12. Calculating Per Cent of Constituents in a Compound. A chemist must often calculate the per cent of a constituent in a substance, using as a basis his knowledge of the chemical formula of the compound under consideration. He does this by applying atomic and molecular weights to the mathematical operations involved in calculating all percentages.

For illustration, suppose it is required to calculate the percentages of hydrogen and oxygen contained in water. By consulting a table of atomic weights it is found that the atomic weight of hydrogen is 1.008 and that of oxygen is 16. These facts afford a basis for calculating the molecular weight of water. Each molecule of water consists of 2 atoms of hydrogen and 1 atom of oxygen. The molecular weight is, therefore, $(2\times1.008)+16$, or 18.016.

* The term *parts* will, unless otherwise specified, refer to *parts by weight.*

TABLE I.—INTERNATIONAL ATOMIC WEIGHTS, 1943

Name	Symbol	Atomic Weight	Name	Symbol	Atomic Weight
Aluminum.....	*Al*	26.97	Molybdenum..	*Mo*	95.95
Antimony......	*Sb*	121.76	Neodymium...	*Nd*	144.27
Argon.........	*A*	39.944	Neon.........	*Ne*	20.183
Arsenic........	*As*	74.91	Nickel........	*Ni*	58.69
Barium........	*Ba*	137.36	Nitrogen......	*N*	14.008
Beryllium......	*Be*	9.02	Osmium......	*Os*	190.20
Bismuth.......	*Bi*	209.00	Oxygen.......	*O*	16.000
Boron.........	*B*	10.82	Palladium.....	*Pd*	106.7
Bromine.......	*Br*	79.916	Phosphorus...	*P*	30.98
Cadmium......	*Cd*	112.41	Platinum.....	*Pt*	195.23
Calcium.......	*Ca*	40.08	Potassium....	*K*	39.096
Carbon........	*C*	12.01	Praseodymium	*Pr*	140.92
Cerium........	*Ce*	140.13	Radium......	*Ra*	226.05
Cesium........	*Cs*	132.91	Radon........	*Rn*	222.0
Chlorine.......	*Cl*	35.457	Rhenium.....	*Re*	186.31
Chromium.....	*Cr*	52.01	Rhodium.....	*Rh*	102.91
Cobalt........	*Co*	58.94	Rubidium.....	*Rb*	85.48
Columbium....	*Cb*	92.91	Ruthenium....	*Ru*	101.7
Copper........	*Cu*	63.57	Samarium.....	*Sm*	150.43
Dysprosium....	*Dy*	162.46	Scandium.....	*Sc*	45.10
Erbium........	*Er*	167.20	Selenium......	*Se*	78.96
Europium......	*Eu*	152.0	Silicon........	*Si*	28.06
Fluorine.......	*F*	19.00	Silver........	*Ag*	107.880
Gadolinium....	*Gd*	156.90	Sodium.......	*Na*	22.997
Gallium.......	*Ga*	69.72	Strontium.....	*Sr*	87.63
Germanium....	*Ge*	72.60	Sulfur........	*S*	32.06
Gold..........	*Au*	197.2	Tantalum.....	*Ta*	180.88
Hafnium.......	*Hf*	178.6	Tellurium.....	*Te*	127.61
Helium........	*He*	4.003	Terbium......	*Tb*	159.2
Holmium......	*Ho*	163.5	Thallium.....	*Tl*	204.39
Hydrogen......	*H*	1.008	Thorium......	*Th*	232.12
Indium........	*In*	114.76	Thulium......	*Tm*	169.4
Iodine.........	*I*	126.92	Tin..........	*Sn*	118.70
Iridium........	*Ir*	193.1	Titanium.....	*Ti*	47.90
Iron..........	*Fe*	55.85	Tungsten.....	*W*	183.92
Krypton.......	*Kr*	83.7	Uranium......	*U*	238.07
Lanthanum....	*La*	138.92	Vanadium....	*V*	50.95
Lead..........	*Pb*	207.21	Xenon........	*Xe*	131.3
Lithium.......	*Li*	6.940	Ytterbium....	*Yb*	173.04
Lutecium......	*Lu*	174.99	Yttrium......	*Y*	88.92
Magnesium....	*Mg*	24.32	Zinc..........	*Zn*	65.38
Manganese.....	*Mn*	54.93	Zirconium.....	*Zr*	91.22
Mercury.......	*Hg*	200.61			

The percentage of hydrogen may be determined from the fact that 18.016 parts of water contain 2.016 parts of hydrogen. In this case the 18.016 parts of water represent the molecular weight of the compound and the 2.016 parts of hydrogen represent the total weight of the element present in the compound. Therefore, the per cent of hydrogen in water may be calculated as follows:

$$\frac{2.016}{18.016} \times 100 = \frac{201.6}{18.016} = 11.19 \text{ per cent}$$

Hence, in 100 parts of water there are 11.19 parts of hydrogen.

The per cent of oxygen is calculated in the same manner.

$$\frac{16}{18.016} \times 100 = \frac{1600}{18.016} = 88.81 \text{ per cent}$$

Hence, in 100 parts of water there are 88.81 parts of oxygen.

13. The method used for calculating the per cent of hydrogen and of oxygen contained in water is applied to all similar problems. It may be stated as a rule.

Rule.—*To find the per cent by weight of an element in a chemical compound, divide the total atomic weight of the element contained in the compound by the molecular weight of the compound and multiply the quotient by* 100.

It may also be stated by the formula

$$\frac{\text{Total atomic weight of element}}{\text{Molecular weight of compound}} \times 100 = \text{per cent of element.}$$

EXAMPLE 1.—The formula for potassium chlorate is $KClO_3$. What is the per cent of each element in the compound?

SOLUTION.—It is first necessary to find the molecular weight of the compound.

Each molecule of $KClO_3$ contains 1 atom of potassium, 1 of chlorine, and 3 of oxygen. Hence, the molecular weight is calculated by means of the atomic weights of the elements, as follows:

$$\begin{array}{rcl} 1 \times 39.096 & = & 39.096, \text{ for potassium} \\ 1 \times 35.457 & = & 35.457, \text{ for chlorine} \\ 3 \times 16.000 & = & \underline{48.000}, \text{ for oxygen} \\ \text{Total} & & 122.553 = \text{molecular weight of potassium chlorate.} \end{array}$$

87760

Then by the preceding method, the per cent of each element is found in the following manner:

$$\text{Per cent of potassium} = \frac{39.096}{122.553} \times 100 = 31.90. \quad \text{Ans.}$$

$$\text{Per cent of chlorine} = \frac{35.457}{122.553} \times 100 = 28.93. \quad \text{Ans.}$$

$$\text{Per cent of oxygen} = \frac{48}{122.553} \times 100 = 39.17. \quad \text{Ans.}$$

The calculation may be checked by finding the sum of the various per cents, which should always be approximately equal to 100.

EXAMPLE 2.—Ferric oxide has the formula Fe_2O_3. What per cent of iron is present in the compound?

SOLUTION.—Each molecule of ferric oxide contains 2 atoms of iron and 3 of oxygen. The molecular weight is, therefore, found as follows:

$$\begin{array}{rl} 2\times 55.85 = & 111.70\text{, for iron} \\ 3\times 16.00 = & \underline{48.00}\text{, for oxygen} \\ \text{Total} & 159.70 = \text{molecular weight of ferric oxide.} \end{array}$$

The per cent of iron is

$$\frac{111.70}{159.70} \times 100 = 69.943. \quad \text{Ans.}$$

EXAMPLE 3.—What per cent of copper is contained in copper sulfate, $CuSO_4 \cdot 5H_2O$?

SOLUTION.—Each molecule of copper sulfate contains 1 atom of copper, 1 atom of sulfur, 9 atoms of oxygen, and 10 atoms of hydrogen. The molecular weight is, therefore, found as follows:

$$\begin{array}{rl} 1\times 63.57 = & 63.57\text{, for copper} \\ 1\times 32.06 = & 32.06\text{, for sulfur} \\ 9\times 16.00 = & 144.00\text{, for oxygen} \\ 10\times 1.008 = & \underline{10.08}\text{, for hydrogen} \\ \text{Total} & 249.71 = \text{molecular weight of copper sulfate.} \end{array}$$

The per cent of copper is

$$\frac{63.57}{249.71} \times 100 = 25.457. \quad \text{Ans.}$$

14. It is sometimes necessary to calculate the per cent of a constituent consisting of more than one element. In such cases the molecular weight of the constituent is used in the calculation. The following examples will illustrate the method to be used.

EXAMPLE 1.—Calculate the per cent of calcium oxide, or lime, CaO, contained in calcium carbonate, $CaCO_3$.

SOLUTION.—The molecular weight of calcium carbonate is found in the manner previously described.

$$\begin{array}{rl} 1\times 40.08 = & 40.08\text{, for calcium} \\ 1\times 12.01 = & 12.01\text{, for carbon} \\ 3\times 16.00 = & \underline{48.00}\text{, for oxygen} \\ \text{Total} & 100.09 = \text{molecular weight of calcium carbonate.} \end{array}$$

The molecular weight of calcium oxide must also be found.

$$\begin{array}{rl} 1\times 40.08 = & 40.08\text{, for calcium} \\ 1\times 16.00 = & \underline{16.00}\text{, for oxygen} \\ \text{Total} & 56.08 = \text{molecular weight of calcium oxide.} \end{array}$$

Therefore, the per cent of calcium oxide in calcium carbonate is

$$\frac{56.08}{100.09}\times 100 = 56.029 \quad \text{Ans.}$$

EXAMPLE 2.—Calculate the per cent of carbon dioxide, CO_2, in sodium carbonate, Na_2CO_3.

SOLUTION.—The molecular weight of sodium carbonate is found in the following manner:

$$\begin{array}{rl} 2\times 22.997 = & 45.994\text{, for sodium} \\ 1\times 12.010 = & 12.010\text{, for carbon} \\ 3\times 16.000 = & \underline{48.000}\text{, for oxygen} \\ \text{Total} & 106.004 = \text{molecular weight of sodium carbonate.} \end{array}$$

The molecular weight of carbon dioxide is

$$\begin{array}{rl} 1\times 12.01 = & 12.01\text{, for carbon} \\ 2\times 16.00 = & \underline{32.00}\text{, for oxygen} \\ \text{Total} & 44.01 = \text{molecular weight of carbon dioxide.} \end{array}$$

Therefore, the per cent of carbon dioxide is

$$\frac{44.01}{106.004}\times 100 = 41.517. \quad \text{Ans.}$$

EXAMPLE 3.—Calculate the per cent of phosphorus pentoxide, P_2O_5, contained in sodium phosphate, $Na_2HPO_4 \cdot 12H_2O$.

SOLUTION.—The principle involved in finding the per cent of a group of atoms is the same as that used in finding the per cent of a single atom. In the formula $Na_2HPO_4 \cdot 12H_2O$, there is only 1 atom of phosphorus, but the compound P_2O_5 contains 2 atoms of phosphorus. Therefore, in order to find the per cent of phosphorus pentoxide in sodium phosphate, the formula for the latter must be multiplied by 2. The formula is then

$2Na_2HPO_4 \cdot 12H_2O$. The per cent of P_2O_5 may now be found in the usual manner but, in order to simplify the problem as much as possible, the multiplication as indicated by the coefficient 2 is first carried out and the formula becomes $Na_4H_2P_2O_8 \cdot 24H_2O$. Taking up each atom in regular order, beginning with sodium, the molecular weight is calculated as follows:

$$\begin{array}{rl}
4 \times 22.997 = 91.998, & \text{for sodium} \\
2 \times 1.008 = 2.016, & \text{for hydrogen} \\
2 \times 30.980 = 61.960, & \text{for phosphorus} \\
8 \times 16.000 = 128.000, & \text{for oxygen} \\
48 \times 1.008 = 48.384, & \text{for hydrogen} \\
24 \times 16.000 = \underline{384.000}, & \text{for oxygen} \\
\text{Total} \qquad 716.348 & = \text{molecular weight of } Na_4H_2P_2O_8 \cdot 24H_2O
\end{array}$$

The molecular weight of P_2O_5 is

$$\begin{array}{rl}
2 \times 30.980 = 61.960, & \text{for phosphorus} \\
5 \times 16.000 = \underline{80.000}, & \text{for oxygen} \\
\text{Total} \qquad 141.960 & = \text{molecular weight of } P_2O_5
\end{array}$$

Therefore, the per cent of P_2O_5 is

$$\frac{141.960}{716.348} \times 100 = 19.81. \quad \text{Ans.}$$

EXAMPLE 4.—Calculate the per cent of water in copper sulfate, $CuSO_4 \cdot 5H_2O$.

SOLUTION.—The molecular weight of $CuSO_4 \cdot 5H_2O$ is determined as shown in Example 3, Art. 13.

$$\begin{array}{rl}
1 \times 63.57 = 63.57, & \text{for copper} \\
1 \times 32.06 = 32.06, & \text{for sulfur} \\
9 \times 16.00 = 144.000, & \text{for oxygen} \\
10 \times 1.008 = \underline{10.08}, & \text{for hydrogen} \\
\text{Total} \qquad 249.71 & = \text{molecular weight of } CuSO_4 \cdot 5H_2O.
\end{array}$$

Since there are five molecules of H_2O present in $CuSO_4 \cdot 5H_2O$, the amount of H_2O present in $CuSO_4 \cdot 5H_2O$ is equal to 5 times its molecular weight, or $5H_2O$. Therefore,

$$\begin{array}{rl}
10 \times 1.008 = 10.08, & \text{for hydrogen} \\
5 \times 16.000 = \underline{80.00}, & \text{for oxygen} \\
\text{Total} \qquad 90.08 & = \text{molecular weight of } 5H_2O.
\end{array}$$

Therefore, the per cent of water is

$$\frac{90.08}{249.71} \times 100 = 36.07. \quad \text{Ans.}$$

EXAMPLE 5.—Calculate the per cent of FeO in ferric oxide, Fe_2O_3.

SOLUTION.—The molecular weight of Fe_2O_3 is determined as follows:

$$
\begin{array}{lll}
2\times 55.85 = & 111.70, & \text{for iron} \\
3\times 16.00 = & \underline{48.00}, & \text{for oxygen} \\
\text{Total} & 159.70 & = \text{molecular weight of } Fe_2O_3.
\end{array}
$$

The molecular weight of FeO is

$$
\begin{array}{lll}
1\times 55.85 = & 55.85, & \text{for iron} \\
1\times 16.00 = & \underline{16.00}, & \text{for oxygen} \\
\text{Total} & 71.85 & = \text{molecular weight of } FeO.
\end{array}
$$

Since there are 2 molecules of FeO present in Fe_2O_3, the amount of FeO present in Fe_2O_3 is equal to 2 times its molecular weight, or $2\times 71.85 = 143.70$.

Therefore, the per cent of FeO is

$$\frac{143.70}{159.70}\times 100 = 89.98. \quad \text{Ans.}$$

CALCULATING QUANTITIES OF CONSTITUENTS

15. To Calculate Quantities in Chemical Problems. Chemists are required to calculate the quantities of substances needed to produce certain chemical changes and the quantities of the products formed. Chemical equations representing the changes are used as a basis for these calculations, and, as they must be properly written if the calculation is to be correct, a review of the methods for ascertaining whether an equation is correct will be helpful at this point.

First of all, a chemical equation is not correct unless it represents a change that actually takes place and can be reproduced. Likewise, the quantities by weight of the materials which react can never be greater nor less than the quantities by weight of the materials produced, for matter can be neither created nor destroyed. In other words, the sum of the weights of the substances used, calculated from the atomic weights of the elements involved, on one side of the equation must equal the sum of the weights of the products produced on the other side of the equation. Finally, the number of atoms of any element on one side of an equation must equal the number of atoms of that element on the other side. If a chemical equation meets all of these requirements, it is correctly written and can be used as a basis for the calculation of quantities involved in chemical changes.

As an illustration, consider the change that takes place when magnesium, Mg, is burned to form magnesium oxide, MgO. The valence of magnesium is 2 and that of oxygen is 2. Hence, 1 atom of magnesium is needed to unite with 1 atom of oxygen

$$Mg + O \rightarrow MgO$$

This equation is not correct, however, because oxygen is diatomic and always exists in nature as a molecule, O_2, and not as an atom, O, as shown in this equation. Doubling the quantities in the equation will show oxygen as a molecule.

$$2Mg + O_2 \rightarrow 2MgO$$

16. The weights, atomic or molecular, of the substances used and produced are next calculated from the atomic weights of the various elements involved. As the atomic weight of magnesium = 24.32, it follows that 2 atoms of magnesium, $2Mg$, have a weight of $2 \times 24.32 = 48.64$. The atomic weight of oxygen = 16; then 2 atoms of oxygen contained in 1 molecule of oxygen, O_2, have a weight of 32.00. The molecular weight of magnesium oxide, containing 1 atom of magnesium and 1 of oxygen, equals the sum of the atomic weights of magnesium and oxygen, 24.32 and 16, or 40.32. The equation shows 2 molecules of magnesium oxide; it has a weight, therefore, of 2×40.32, or 80.64.

The parts by weight of the substances involved in a chemical change are, for convenience, placed under the respective formulas and symbols of the substances.

$$\begin{array}{c} 2Mg + O_2 \rightarrow 2MgO \\ 48.64 + 32.00 \rightarrow 80.64 \end{array}$$

This equation shows that 48.64 parts by weight of magnesium unite with 32.0 parts of oxygen to form 80.64 parts of magnesium oxide; that 48.64 parts of magnesium form 80.64 parts of magnesium oxide when burned; and that the sum of the weights of magnesium and oxygen equals the weight of magnesium oxide produced.

17. So far, the equation $2Mg + O_2 \rightarrow 2MgO$ has met two of the requirements of a correctly written chemical equation; it represents a change that can be produced by burning mag-

nesium, and the sum of the weights used on one side of the equation is equal to that produced on the other. Likewise, it meets the third requisite, for there are 2 atoms of magnesium and 2 of oxygen on each side of the equation. Hence, the equation is correctly written and can be used as a basis for calculations involving the chemical combination between magnesium and oxygen.

For instance, a chemist may be asked how much magnesium oxide is produced when 100 pounds of magnesium is burned. Such problems are based primarily on the Law of Combining Weights: *In a chemical reaction, combination or reaction takes place by weights which are directly proportional to the atomic or molecular weights of the reacting constituents.* Therefore, given the equation for a chemical reaction, the chemist can calculate the weights of the substances required as well as the weights of the products formed in the reaction. A calculation based on such a direct proportionality between atomic or molecular weights and actual weights is known as a stoichiometric calculation. This fact can be expressed as a proportion.

The ratio of the reacting weight of one substance to its actual weight equals the ratio of the weight of the substance formed to its actual weight.

In the process of burning 100 pounds of magnesium to form magnesium oxide, the ratios representing the reaction may be written as follows:

$$\overset{48.64}{\underset{100 \text{ lb.}}{2Mg}} + O_2 \rightarrow \overset{80.64}{\underset{x}{2MgO}}$$

When the reaction that takes place and the values of the reacting weights are represented in this manner, it is a simple matter to write the correct proportion. In the preceding statement representing the reaction, there are two ratios which are to form a proportion. Arranging these ratios as a proportion, it will assume the following form: $\frac{48.64}{100}=\frac{80.64}{x}$.

Solving the proportion according to the method previously given, the following equation is obtained:

$$48.64x = 80.64 \times 100$$

Therefore, $x=\frac{80.64\times100}{48.64}=165.79$ lb. of MgO. Ans.

If preferred, the ratios $\frac{48.64}{100}=\frac{80.64}{x}$ may be arranged as in the following proportion:

$$48.64 : 100 = 80.64 : x$$

The value of x is then found as follows:

$$x=\frac{80.64\times100}{48.64}=165.79 \text{ lb. of } MgO. \quad \text{Ans.}$$

18. General Method for Solving Problems Involving Weights.—The calculation of weights of elements and compounds involved in chemical changes may be simplified by performing the various steps of the calculation in the following order:

1. Write the chemical equation representing the change. It should be noted that some equations may be written by applying the valence principles. Others that represent reactions not following the general rule must be written from memory or secured from textbooks. In every case, an equation represents merely a change that has been shown by experimental work to take place.

2. Check the accuracy of the equation by noting whether it meets all the requirements of a correctly written equation.

3. Calculate the combining weights of the substances involved in the problem and place these weights over the proper symbols in the equation.

4. Arrange the known and the unknown values as ratios and calculate the unknown value by means of the rules of proportion.

19. The application of the preceding method of calculation will be shown by the following examples:

EXAMPLE 1.—Calculate the weights of sodium chloride, $NaCl$, and sulfuric acid, H_2SO_4, required to produce 100 kilograms of sodium sulfate, Na_2SO_4.

SOLUTION.—The first step in the solution of the problem is to write the equation representing the reaction.

$$2NaCl+H_2SO_4 \rightarrow Na_2SO_4+2HCl$$

It is seen that three substances—sodium chloride, sulfuric acid, and sodium sulfate—are in the solution of the problem. The fourth substance, hydrochloric acid, HCl, is not considered, since it is not required.

According to Art. 18, the next step is to calculate the weights of the substances and place them over the corresponding formulas in the equation.

$$\overset{116.908}{2NaCl} + \overset{98.076}{H_2SO_4} \rightarrow \overset{142.054}{Na_2SO_4} + 2HCl$$

The required weight of sodium sulfate is 100 kilograms, so this weight is written under its formula in the equation. As the weights of the sodium chloride and the sulfuric acid are to be found, these weights are, for the present, indicated by the symbols x and x_1 in the equation. In its present form, the equation will appear as follows:

$$\underset{x}{\overset{116.908}{2NaCl}} + \underset{x_1}{\overset{98.076}{H_2SO_4}} \rightarrow \underset{100\text{ kg.}}{\overset{142.054}{Na_2SO_4}} + 2HCl$$

Omitting the chemical formulas for reasons of clearness, the given ratios may be stated in the following manner:

$$\frac{116.908}{x}, \frac{98.076}{x_1}, \text{ and } \frac{142.054}{100}$$

Each one of the unknown ratios is now combined with the known ratio, $\frac{142.054}{100}$, as a proportion in order to find the values of x and x_1.

Therefore, to calculate the weight of sodium chloride required, the following proportion is written:

$$\frac{116.908}{x} = \frac{142.054}{100}$$

Hence, $$142.054x = 116.908 \times 100$$

$$x = \frac{116.908 \times 100}{142.054} = 82.294 \text{ kg. of } NaCl$$

Similarly, to calculate the weight of the sulfuric acid, the second ratio is employed.

$$\frac{98.075}{x_1} = \frac{142.054}{100}$$

Hence, $$142.054x_1 = 98.076 \times 100$$

$$x_1 = \frac{98.076 \times 100}{142.054} = 69.04 \text{ kg. of } H_2SO_4$$

It follows that 82.294 kg. of sodium chloride and 69.04 kg. of sulfuric acid are required to produce 100 kg. of sodium sulfate.

Example 2.—Potassium acid sulfate, $KHSO_4$, in addition to nitric acid may be produced by adding sulfuric acid to potassium nitrate, KNO_3.

87760

If 500 grams of H_2SO_4 is available, how many grams of $KHSO_4$ may be produced, and how many grams of KNO_3 will be required?

Solution.—The equation representing the reaction, together with the combining weights, the unknown terms, and the given terms, is written as in the last example.

$$\underset{x_1}{\overset{101.104}{KNO_3}} + \underset{500\text{ g.}}{\overset{98.076}{H_2SO_4}} \rightarrow \underset{x}{\overset{136.164}{KHSO_4}} + HNO_3$$

The three ratios may be written

$$\frac{101.104}{x_1}, \frac{98.076}{500}, \text{ and } \frac{136.164}{x}$$

Combining each unknown ratio in turn with the known one, the following proportions may be written:

$$\frac{101.104}{x_1} = \frac{98.076}{500}$$

and

$$\frac{136.164}{x} = \frac{98.076}{500}$$

Hence,

$$98.076x_1 = 101.104 \times 500$$

$$x_1 = \frac{101.104 \times 500}{98.076} = 515.43 \text{ g.}$$

Also,

$$98.076x = 136.164 \times 500$$

$$x = \frac{136.164 \times 500}{98.076} = 694.176 \text{ g.}$$

Hence, if 515.43 g. of potassium nitrate is added to 500 g. of sulfuric acid, 694.176 g. of potassium acid sulfate is produced. Ans.

Example 3.—How many grams of silver, Ag, can be obtained from 1,000 grams of silver sulfate, Ag_2SO_4?

Solution.—The molecular weight of Ag_2SO_4 is 311.82. The atomic weight of Ag is 107.88. It follows that $2Ag = 107.88 \times 2 = 215.76$. The formulas, with the corresponding molecular weights, as well as the given weight of silver sulfate, are written as follows:

$$\underset{1{,}000\text{ g.}}{\overset{311.82}{Ag_2SO_4}} \rightarrow \underset{x}{\overset{215.76}{2Ag}}$$

The following proportion may now be written:

$$\frac{311.82}{1{,}000} = \frac{215.76}{x}$$

Hence,

$$311.82x = 215.76 \times 1{,}000$$

$$x = \frac{215.76 \times 1{,}000}{311.82} = 691.037 \text{ g.} \quad \text{Ans.}$$

20. Derivation of Chemical Formulas From Experimental Data.—To derive the formula of an element it is only necessary to determine how many times the atomic weight of that element is contained in its molecular weight. For example, the atomic weight of hydrogen is 1.008; but upon weighing the gas and comparing it with an equal volume of oxygen, it is found that the molecular weight of hydrogen contains two atoms, and the formula (which always represents one molecule) for hydrogen must be H_2.

The formulas for compounds are derived in a similar way. First, the weight of each element present in one molecular weight of a compound is determined; then the number of atoms needed to account for this weight is determined. For example, chloroform has a molecular weight of approximately 120. Quantitative analysis of chloroform shows that a molecular weight of it contains approximately twelve parts by weight of carbon, one part by weight of hydrogen, and 107 parts by weight of chlorine. These weights are divided by the respective atomic weights of the elements.

$$12 \div 12.01 = 1 \text{ atom of carbon}$$
$$1 \div 1.008 = 1 \text{ atom of hydrogen}$$
$$107 \div 35.457 = \text{approximately 3 atoms of chlorine}$$

Therefore, the formula for chloroform must be $CHCl_3$.

The method of deriving the formula of a compound is stated as a rule as follows:

Rule.—*Divide the weight of each element present in the compound by its atomic weight, in order to determine what multiple of the atomic weight of each element is contained in one molecular weight of the substance.*

Following are more examples showing application of this rule:

EXAMPLE 1.—Phosphoric acid has a molecular weight of 98.004. Quantitative analysis of the acid shows that a molecular weight contains 3.024 parts by weight of hydrogen, 30.98 parts by weight of phosphorus, and 64 parts by weight of oxygen. What is the formula for phosphoric acid?

SOLUTION.—Dividing the weight of the elements present in the compound by their respective atomic weights gives

$$3.024 \div 1.008 = 3 \text{ atoms of hydrogen}$$
$$30.98 \div 30.98 = 1 \text{ atom of phosphorus}$$
$$64 \div 16.00 = 4 \text{ atoms of oxygen}$$

Therefore, the formula for phosphoric acid is H_3PO_4.

EXAMPLE 2.—The molecular weight of methane is 16.042. By quantitative analysis it is found to contain 74.86 per cent of carbon and 25.14 per cent of hydrogen. What is its formula?

SOLUTION.—Since 74.86 per cent of methane is carbon, 1 gram-molecular weight contains $16.042 \times \frac{74.86}{100} = 12.01$ g. of carbon. Also, since 1 gram-atomic weight of carbon = 12.01 g., 1 molecular weight of methane contains $\frac{12.01}{12.01}$, or 1 atomic weight of carbon. Each molecule of methane, therefore, contains 1 carbon atom.

Likewise, since 25.14 per cent of methane is hydrogen, 1 gram-molecular weight contains $16.042 \times \frac{25.14}{100} = 4.032$ g. of hydrogen. Therefore, since 1 gram-atomic weight of hydrogen = 1.008 g., 1 molecular weight of methane contains $\frac{4.032}{1.008} = 4$ atomic weights of hydrogen. Each molecule of methane, therefore, contains 4 atoms of hydrogen.

Hence, the molecular formula for methane is CH_4. Ans.

21. Solution of Problems Involving Gases.—Volumes of gases, as well as weights of materials, may enter into chemical problems. In problems involving gases, important factors are: temperature, pressure, and density. For example, a chemical change may result in the production of a gas, the volume of which must be determined. Problems of this nature are solved by converting gaseous volumes to weight equivalents, and weights of gases to volume.

Two general methods may be used for finding the weight of a liter of any gas.

1. The weight of a liter of gas may be obtained by multiplying its density, which may be taken as one-half of its molecular weight, by the weight of 1 liter of hydrogen at a temperature of 0°C. and a pressure of 760 millimeters. The weight of 1 liter of hydrogen at this temperature and pressure is .089873 gram.

Since the molecular weight of hydrogen sulfide, H_2S, is 34.076, its density is 17.038. Therefore, the weight of 1 liter of H_2S may be obtained as follows:

$$17.038 \times .089873 = 1.531 \text{ grams.}$$

2. The approximate weight of a liter of any gas may also be calculated by using the following rule: *The molecular weight of a gas at 0°C. and 760 millimeters pressure is contained in approximately 22.4 liters of the gas.*

The molecular weight of H_2S is 34.076, and 34.076 grams of H_2S is contained in approximately 22.4 liters of the gas. Hence, 1 liter of H_2S would weigh $34.076 \div 22.4 = 1.521$ grams. Any slight difference in results obtained by the use of the two methods is negligible.

The molecular weight of oxygen is 32, and 32 grams is contained in approximately 22.4 liters. Hence, 1 liter would weigh $32 \div 22.4 = 1.4285$ grams.

It may be necessary to determine the volume of a gas under any one of four different conditions. The conditions and methods of determination are as follows:

Case I.—*To find the volume of a gaseous product at normal temperature and pressure, or 0°C. and 760 millimeters.*

EXAMPLE.—What volume of oxygen at normal temperature and pressure can be obtained by decomposing 30 grams of potassium chlorate, $KClO_3$?

SOLUTION.—The equation representing the reaction and the weights involved should first be written.

$$\frac{\overset{245.106}{2KClO_3}}{30} \rightarrow 2KCl + \frac{\overset{96}{3O_2}}{x}$$

Hence,
$$\frac{245.016}{30} = \frac{96}{x}$$

$$245.016x = 96 \times 30$$

$$x = \frac{2{,}880}{245.016} = 11.75 \text{ g. of oxygen.}$$

One liter of oxygen weighs $16 \times .089873 = 1.438$ g. Hence, $11.75 \div 1.438 = 8.17$ liters. Ans.

SECOND METHOD.—The volumes of oxygen involved are used in this method instead of the weights.

$$\overset{245.016}{\underset{30}{2KClO_3}} \rightarrow 2KCl + \overset{3\times 22.4 \text{ liters}}{\underset{x}{3O_2}}$$

Hence,

$$\frac{245.016}{30}=\frac{3\times 22.4}{x}$$

$$245.016x = 67.2\times 30$$

$$x=\frac{67.2\times 30}{245.016}=8.22 \text{ liters. Ans.}$$

Case II.—*To find the volume of a gas at other than normal temperature, the pressure remaining constant.*

The law of Charles or Gay-Lussac may be stated as follows: *The volume of a gas varies as the absolute temperature.* In other words, if the absolute temperature of a certain volume of gas is increased, the volume which the gas will occupy will also increase in direct proportion to the rise in absolute temperature, and the reverse holds true if the absolute temperature of a certain volume of gas is decreased. This law may be expressed by the proportion

$$\frac{V}{V'}=\frac{T}{T'}$$

in which V = original volume;
V' = new volume;
T = original absolute temperature $(273+t)$;
T' = new absolute temperature $(273+t')$;
t = original centigrade temperature;
t' = new centigrade temperature.

Note.—Absolute temperature is equal to centigrade temperature plus 273.

EXAMPLE.—A gas occupies 200 liters at 50° C. What volume will it occupy at −5° C.?

SOLUTION.—From the foregoing proportion, the following is obtained:

$$V'T = VT'$$

$$V' = \frac{VT'}{T}$$

By substitution in this formula,

$$V'=\frac{200\times(273-5)}{273+50}=\frac{200\times 268}{323}=165.94 \text{ liters. Ans.}$$

Case III.—*To find the volume of a gas at other than normal pressure, the temperature remaining constant.*

Boyle's law may be stated as follows:

The volume of a gas varies inversely as the pressure to which it is subjected. In other words, if pressure is brought to bear on a known volume of gas, this volume will decrease as the pressure increases. This law may be expressed by the proportion

$$\frac{V}{V'}=\frac{P'}{P}$$

in which V = original volume;
V' = new volume;
P' = new pressure;
P = original pressure.

EXAMPLE 1.—What volume will 500 liters of a gas, under a pressure of 770 millimeters, occupy under a pressure of 700 millimeters?

SOLUTION.—From the foregoing proportion, the following is obtained:

$$V'P'=VP$$

$$V'=\frac{VP}{P'}$$

By substitution in this formula,

$$V'=\frac{500\times 770}{700}=550 \text{ liters of oxygen. Ans.}$$

EXAMPLE 2.—A certain quantity of air occupies 1,000 milliliters under a pressure of 720 millimeters. What volume will it occupy if the pressure is increased to 780 millimeters?

SOLUTION.—Use is made of the formula

$$V'=\frac{VP}{P'}$$

By substitution in this formula,

$$V'=\frac{1{,}000\times 720}{780}=923.08 \text{ ml. Ans.}$$

Case IV.—Sometimes it becomes necessary to correct the volume of a gas for both temperature and pressure at the same time. This can, of course, be performed by correcting the volume for one factor, and then by using the corrected volume as the starting point, for the other factor. By combining the

two formulas for the correction of volume, the same end can be reached by one operation by means of the following formula:

$$V' = \frac{T'PV}{TP'}$$

in which V' = new volume;
V = original volume;
T' = new absolute temperature;
T = original absolute temperature;
P' = new pressure;
P = original pressure.

The following examples show applications of the formula:

EXAMPLE 1.—A gas occupies 100 liters at a temperature of 20° C. and under a pressure of 780 millimeters. What will its volume be at a temperature of −5° C. and under a pressure of 760 millimeters?

SOLUTION.—By substituting the known values in the formula,

$$V' = \frac{(273-5)\times 780\times 100}{(273+20)\times 760} = 93.87 \text{ liters. Ans.}$$

EXAMPLE 2.—A volume of carbon dioxide gas occupies 20 liters at 40° C. and 780 millimeters. How many liters will it occupy at 0° C. and 760 millimeters?

SOLUTION.—By substituting the known values in the formula,

$$V' = \frac{273\times 780\times 20}{(273+40)\times 740} = 18.38 \text{ liters. Ans.}$$

22. Solution of Problems Involving Weights and Gaseous Volumes.—In chemical work, a chemist is sometimes required to determine how much, by weight, of a substance is needed to produce a certain volume of a gas under definite conditions of temperature and pressure; or how much, by volume, of a gas under certain conditions of temperature and pressure is formed when definite amounts of substances are chemically combined. These determinations are based on the reduction of the volume of the gas under various conditions of temperature and pressure to the volume at 0° C. and 760 millimeters, and then on changing to the weight equivalents by using the rule that the weight of 1 liter of a gas is equal to its density multiplied by the weight of 1 liter of hydrogen at 0° C. and 760 millimeters, or vice versa.

The following examples show how problems involving both weights and volumes are solved:

EXAMPLE 1.—If 200 grams of mercuric oxide, HgO, are decomposed into mercury and oxygen, how many liters of oxygen will be obtained at a temperature of 50° C. and a pressure of 790 millimeters?

SOLUTION.—The equation representing the reaction and the weights involved is first written.

$$\overset{433.22}{\underset{200}{2HgO}} \rightarrow 2Hg + \overset{32}{\underset{x}{O_2}}$$

Hence,
$$\frac{433.22}{200}=\frac{32}{x}$$

$$433.22x=32\times 200$$

$$x=\frac{32\times 200}{433.2}=14.77 \text{ g. of oxygen.}$$

1 liter of oxygen weighs $16\times .089873=1.438$ g.

Hence, $14.77 \text{ g.}=14.77\div 1.438=10.25$ liters of oxygen.

Use is then made of the formula

$$V'=\frac{T'PV}{TP'}$$

By substituting the known values in the formula,

$$V'=\frac{(273+50)\times 760\times 10.25}{273\times 790}=11.67 \text{ liters. Ans.}$$

This problem is a calculation in which a conversion of weight to volume is involved. In problems of this type, it is first necessary to calculate the weight of the volume of the substance required; second, to convert the weight to its equivalent volume at 0° C. and 760 millimeters (expressed in liters); third, to change this volume to the volume at the required temperature and pressure.

The following example is a calculation involving a conversion from volume to weight:

Example 2.—In order to prepare 10 liters of hydrogen at 40° C. and 720 millimeters by the action of sulfuric acid on zinc, how much zinc must be used?

SOLUTION.—The first step is to reduce the volume of the gas, 10 liters, at 40° C. and 720 millimeters to the volume which the gas would occupy at 0° C. and 760 millimeters.

$$V'=\frac{273\times 720\times 10}{(273+40)\times 760}=8.26 \text{ liters of hydrogen.}$$

The second step is to determine the weight of 8.26 liters of hydrogen. One liter weighs .089873 g., 8.26 liters weighs $8.26 \times .089873 = .7423$ g. Next, the equation representing the reaction and the weights involved is written.

$$\overset{65.38}{\underset{x}{Zn}} + H_2SO_4 \rightarrow ZnSO_4 + \overset{2.016}{\underset{.7423}{H_2}}$$

Hence,
$$\frac{65.38}{x} = \frac{2.016}{.7423}$$
$$2.016x = 65.38 \times .7423$$
$$x = \frac{65.38 \times .7423}{2.016} = 24.06 \text{ g. of zinc. Ans.}$$

This problem, involving a conversion from volume to weight, includes several definite steps. First, the volume of the gas required is changed to its volume at 0° C. and 760 millimeters; second, the volume at 0° C. and 760 millimeters is converted to its weight equivalent in grams; third, the weight of gas needed is used as a basis for calculating the weights of substances needed to produce the required volume of gas.

23. The best method by which a student may become familiar with the solution of chemical problems is to solve all kinds in such a way that every step will be clearly understood and that problems of like nature will be recognized when met in industrial work. Following are examples for practice that will serve to meet these requirements if the student carefully solves each of them so that he gets the correct answer and knows why he performed each step in the calculation.

EXAMPLES FOR PRACTICE

1. Calculate the percentage composition of sodium acid sulfate, $NaHSO_4$.

$$\text{Ans.} \begin{cases} Na = 19.15\% \\ H = 0.84\% \\ S = 26.70\% \\ O = 53.30\% \end{cases}$$

2. Calculate the percentage composition of ferric chloride, $FeCl_3$.

$$\text{Ans.} \begin{cases} Fe = 34.42\% \\ Cl = 65.57\% \end{cases}$$

3. Calculate the percentage composition of potassium tetraborate, $K_2B_4O_7$.

$$\text{Ans.} \begin{cases} K = 33.49\% \\ B = 18.54\% \\ O = 47.97\% \end{cases}$$

4. What quantity of lime, CaO, can be obtained from 1,000 pounds of calcium carbonate, $CaCO_3$? Ans. 560.295 lb.

5. How much arsenious oxide, As_2O_3, may be obtained from 100 pounds of magnesium pyroarsenate, $Mg_2As_2O_7$? Ans. 63.711 lb.

6. What percentage of sulfur trioxide, SO_3, is contained in barium sulfate, $BaSO_4$? Ans. 34.298%

7. Zinc chloride, $ZnCl_2$, may be made by treating zinc oxide, ZnO, with hydrochloric acid, HCl. The reaction is represented by the following equation:

$$ZnO+2HCl \rightarrow ZnCl_2+H_2O$$

(*a*) How much ZnO will react with 100 kilograms of HCl?
(*b*) How much HCl will be necessary to make 150 kilograms of $ZnCl_2$?

Ans. { (*a*) 111.586 kg.
(*b*) 80.265 kg.

8. The reaction between ammonium chloride, NH_4Cl, and lime, CaO, is represented by the equation

$$2NH_4Cl+CaO \rightarrow 2NH_3+CaCl_2+H_2O$$

How much lime will be required to make 30 pounds of ammonia, NH_3? Ans. 49.38 lb.

9. A compound has a molecular weight of 153.888 and the following composition: Silver, 70.13%; oxygen, 20.77%; and nitrogen, 9.09%. Determine the formula from these figures. Ans. $AgNO_2$.

10. A compound contains 43.4% sodium, 11.32% carbon, and 45.28% oxygen. Its molecular weight is 106.004. What is its formula? Ans. Na_2CO_3

11. The approximate density of oxygen is 16. What is the weight of 100 liters of oxygen at 0° C. and 760 millimeters? Ans. 143.7968 g.

12. The approximate density of hydrogen sulfide, H_2S, is 17. What is the weight of 10 liters of the gas at 0° C. and 760 millimeters? Ans. 15.278 g.

13. What is the weight of 50 liters of nitrogen at 0° C. and 760 millimeters, the approximate density of nitrogen being 14? Ans. 62.911 g.

14. Calculate the volume, in liters, of 250 grams of oxygen at 0° C. and 760 millimeters. Ans. 173.75 liters

15. Hydrogen is formed by the action of sulfuric acid on zinc.

$$Zn+H_2SO_4 \rightarrow ZnSO_4+H_2$$

(*a*) What amount of $ZnSO_4$ is formed when 15 grams of zinc is treated with sulfuric acid? Ans. 37.038 g.

(*b*) How much zinc is required to form zinc sulfate with 20 grams of sulfuric acid? Ans. 13.33 g.

(*c*) How many liters of hydrogen are formed at 0° C. and 760 millimeters of pressure when 45 grams of zinc is treated with sulfuric acid? Ans. 15.43 liters

(*d*) What volume of hydrogen is formed in (*c*) at 12° C. and 754 millimeters of pressure? Ans. 16.43 liters

16. A gas occupies a volume of 500 liters at 30° C. and 760 millimeters. What volume will it occupy if the temperature and pressure are changed to 20° C. and 750 millimeters? Ans. 510.35 liters

RELATION OF SPECIFIC GRAVITY TO DEGREES BAUMÉ

24. As the strength of all the common mineral acids, such as sulfuric, nitric, and hydrochloric, and solutions of some alkalies are designated by their specific gravities (sp. gr.) or by degrees Baumé (° Bé), it is important that one should know the relation existing between these values and to be familiar with the rapid practical methods by which each is obtained.

25. The *specific gravity* of a solution is the weight of a volume of the solution compared with the weight of an equal volume of water at the same temperature. For instance, the specific gravity of ordinary C. P. (chemically pure) sulfuric acid is 1.84, which may be interpreted to mean that a volume of this acid is 1.84 times as heavy as an equal volume of water at the same temperature. In other words, the weight of 1 milliliter of the acid, at 15.56° C., may be taken as 1.84 grams. Therefore, instead of weighing out the acid which may be called for in an experiment, approximate weights may be obtained by measuring out the volume corresponding to this weight.

EXAMPLE.—The directions for a certain experiment call for 100 grams C. P. sulfuric acid, specific gravity (sp. gr.) 1.84. How may this weight of acid be approximately obtained in the event that a balance is not available?

SOLUTION.—One milliliter (1 ml.) weighs 1.84 g.

Hence, $100 \div 1.84 = 54.3$ ml., the volume of acid corresponding to 100 g.

26. One form of instrument commonly used for determining degrees Baumé is called a *hydrometer*, which is illustrated in Fig. 1. This instrument is usually made of glass and is weighted at one end so that it will float in a liquid in a vertical position.

Several types of hydrometers are in use, each designed for a special purpose, but the Baumé hydrometer, which is generally used, is the only one which need be described. Of this type of hydrometer, two kinds are used, one for liquids lighter than water (shown at the right in the illustration) and the other for liquids heavier than water (shown at the left in the illustration). When placed in pure water at 15.56° C. or 60° F., the first floats so that the graduation on its stem, marked 10, coincides with the surface of the water; whereas the second sinks until the surface of the water is at the graduation marked 0.

To use either a hydrometer showing specific gravities or the Baumé hydrometer showing degrees Baumé, the instrument is placed in a cylinder containing the liquid at the proper temperature, usually 15.56° C. or 60° F.; and the specific gravity or degrees Baumé are read directly from the stem at the surface of the liquid.

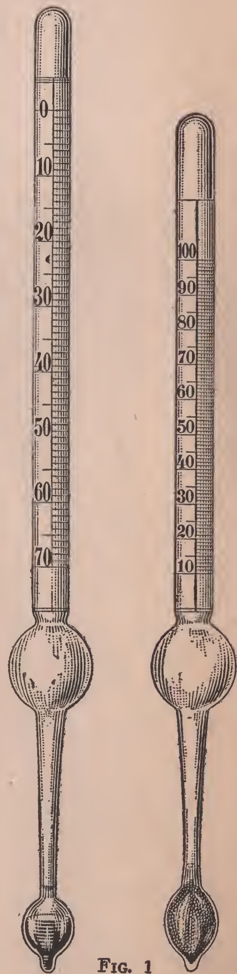


FIG. 1

27. Calculation of Degrees Baumé and Specific Gravity.—Conversion of degrees Baumé to specific gravity and specific gravity to degrees Baumé can be easily accomplished by the aid of the following formulas:

For Liquids Lighter Than Water

$$\text{Specific gravity} = \frac{140}{\text{degrees Baumé} + 130}$$

$$\text{Degrees Baumé} = \frac{140}{\text{specific gravity}} - 130$$

For Liquids Heavier Than Water

$$\text{Specific gravity} = \frac{145}{145 - \text{degrees Baumé}}$$

$$\text{Degrees Baumé} = 145 - \frac{145}{\text{specific gravity}}$$

The specific gravity of a solution, whether of an acid, an alkali, or a salt, depends upon the per cent of acid, alkali, or salt in solution. In order to determine quickly the strength, in per cent, of a certain solution. Tables II, III, IV, and V based upon the results of actual analyses have been published. They show the relation existing between per cent, strength, specific gravity, and degrees Baumé, of frequently used chemicals such as mineral acids, and solutions of sodium hydroxide, potassium hydroxide, ferrous sulfate, and copper sulfate.

28. Explanation of Tables.—The expression $\frac{60°}{60°}$ F. or $\frac{15.56°}{15.56°}$ C. means that the specific gravity has been obtained by comparing the weight of the liquid at 60° F., or at 15.56° C., with the weight of an equal volume of water at the same temperature. Frequently the temperature at which the specific gravity is taken is given as $\frac{20°}{4°}$ C., which means that the comparison of the weight of the liquid with the weight of an equal volume of water was made with the liquid at 20° C., and the water at 4° C.

In Table II, specific gravities are given in the first column on the left, beginning with 1.00. The third figure of the specific gravity is then obtained from the number heading each vertical column. To convert specific gravity into degrees Baumé, proceed as follows: Suppose that the specific gravity

TABLE II*

DEGREES BAUMÉ CORRESPONDING TO SPECIFIC GRAVITIES AT $\frac{60°}{60°}$ F. $\left(\frac{15.56°}{15.56°}\text{ C.}\right)$ FOR LIQUIDS HEAVIER THAN WATER

Sp. Gr. $\frac{15.56°}{15.56°}$ Cent.	0	1	2	3	4	5	6	7	8	9
1.00	0.000	0.145	0.289	0.434	0.578	0.721	0.865	1.008	1.151	1.293
1.01	1.436	1.578	1.719	1.816	2.002	2.143	2.283	2.424	2.564	2.704
1.02	2.843	2.982	3.121	3.260	3.399	3.537	3.675	3.812	3.950	4.087
1.03	4 223	4.360	4.496	4.632	4.768	4.903	5.038	5.174	5.308	5.443
1.04	5.577	5.711	5.845	5.978	6.111	6.244	6.377	6.509	6.641	6.773
1.05	6.905	7.036	7.167	7.298	7.429	7.559	7.689	7.819	7.949	8.078
1.06	8.208	8.336	8.465	8.594	8.722	8.850	8.978	9.105	9.232	9.359
1.07	9.486	9.613	9.739	9.865	9.991	10.116	10.242	10.367	10.492	10.616
1.08	10.741	10.865	10.989	11.113	11.236	11.359	11.483	11.605	11.728	11.850
1.09	11.972	12.094	12.216	12.338	12.459	12.580	12.701	12.821	12.942	13.062
1.10	13.182	13.302	13.421	13.540	13.659	13.778	13.897	14.015	14.134	14.252
1.11	14.370	14.487	14.604	14.721	14.838	14.955	15.072	15.188	15.304	15.420
1.12	15.536	15.561	15.767	15.882	15.997	16.111	16.226	16.340	16.454	16.568
1.13	10.682	16.795	16.908	17.021	17.134	17.247	17.359	17.471	17.583	17.695
1.14	17.807	17.919	18.030	18.141	18.252	18.363	18.473	18.583	18.693	18.803
1.15	18.913	19.023	19.132	19.241	19.350	19.459	19.568	19.676	19.784	19.892
1.16	20.000	20.108	20.215	20.322	20.430	20.536	20.643	20.750	20.856	20.962
1.17	21.068	21.174	21.280	21.385	21.491	21.596	21.701	21.806	21.910	22.014
1.18	22.119	22.223	22.327	22.430	22.534	22.637	22.740	22.843	22.946	23.049
1.19	23.151	23.254	23.356	23.458	23.560	23.661	23.763	23.864	23.965	24.066
1.20	24.167	24.267	24.368	24.468	24.568	24.668	24.768	24.868	24.967	25.066
1.21	25.165	25.264	25.363	25.462	25.560	25.658	25.755	25.855	25.952	26.050
1.22	26.148	26.245	26.342	26.439	26.536	26.633	26.729	26.826	26.922	27.018
1.23	27.114	27.210	27.305	27.401	27.496	27.591	27.686	27.781	27.876	27.970
1.24	28.065	28.159	28.253	28.347	28.441	28.534	28.628	28.721	28.814	28.907
1.25	29.000	29.093	29.185	29.278	29.370	29.462	29.554	29.646	29.738	29.829
1.26	29.921	30.012	30.103	30.194	30.285	30.376	30.466	30.556	30.647	30.737
1.27	30.827	30.917	31.006	31.096	31.185	31.275	31.364	31.453	31.542	31.630
1.28	31.719	31.807	31.896	31.984	32.072	32.160	32.247	32.335	32.422	32.510
1.29	32.597	32.684	32.771	32.858	32.944	33.031	33.117	33.204	33.290	33.376
1.30	33.462	33.547	33.633	33.718	33.804	33.889	33.974	34.059	34.144	34.229
1.31	34.313	34.397	34.482	34.566	34.650	34.734	34.818	34.901	34.985	35.068
1.32	35.152	35.235	35.318	35.401	35.483	35.566	35.649	35.731	35.813	35.895
1.33	35.977	36.059	36.141	36.223	36.304	36.386	36.467	36.548	36.629	36.710
1.34	36.791	36.872	36.952	37.033	37.113	37.193	37.273	37.353	37.433	37.513
1.35	37.593	37.672	37.751	37.831	37.910	37.989	38.068	38.147	38.225	38.304
1.36	38.382	38.461	38.539	38.617	38.695	38.773	38.851	38.928	39.006	39.803
1.37	39.161	39.238	39.315	39.392	39.469	39.546	39.622	39.609	39.775	39.851
1.38	39.928	40.004	40.080	40.156	40.231	40.307	40.382	40.458	40.533	40.608
1.39	40.683	40.758	40.833	40.908	40.983	41.057	41.132	41.206	41.280	41.355
1.40	41.429	41.503	41.576	41.650	41.724	41.797	41.871	41.944	42.017	42.090
1.41	42.163	42.236	42.309	42.381	42.454	42.527	42.599	42.671	42.743	42.815
1.42	42.887	42.959	43.031	43.103	43.174	43.246	43.317	43.388	43.459	43.530
1.43	43.601	43.672	43.743	43.814	43.884	43.955	44.025	44.095	44.166	44.236
1.44	44.306	44.376	44.445	44.515	44.585	44.654	44.724	44.793	44.862	44.931
1.45	45.000	45.069	45.138	45.207	45.275	45.344	45.412	45.481	45.549	45.617

*Data obtained from Circular No. 19, Bureau of Standards.

TABLE II—(*Continued*)

DEGREES BAUMÉ CORRESPONDING TO SPECIFIC GRAVITIES AT $\frac{60°}{60°}$ F. $\left(\frac{15.56°}{15.56°}\text{ C.}\right)$ FOR LIQUIDS HEAVIER THAN WATER

Sp. Gr. 15.56°/15.56° Cent.	0	1	2	3	4	5	6	7	8	9
1.46	45.685	45.753	45.821	45.889	45.956	46.024	46.091	46.159	46.226	46.293
1.47	46.361	46.428	46.495	46.562	46.628	46.695	46.762	46.828	46.894	46.961
1.48	47.027	47.093	47.159	47.225	47.291	47.357	47.423	47.488	47.554	47.619
1.49	47.685	47.750	47.815	47.880	47.945	48.010	48.075	48.140	48.204	48.269
1.50	48.333	48.398	48.462	48.526	48.591	48.655	48.719	48.782	48.846	48.910
1.51	48.974	49.037	49.101	49.164	49.227	49.290	49.354	49.417	49.480	49.543
1.52	49.605	49.668	49.731	49.793	49.856	49.918	49.980	50.043	50.105	50.167
1.53	50.229	50.291	50.353	50.414	50.476	50.538	50.599	50.660	50.722	50.783
1.54	50.844	50.905	50.966	51.027	51.088	51.149	51.210	51.270	51.331	51.391
1.55	51.452	51.512	51.572	51.632	51.692	51.752	51.812	51.872	51.932	51.992
1.56	52.051	52.111	52.170	52.230	52.289	52.348	52.407	52.467	52.526	52.585
1.57	52.643	52.702	52.761	52.820	52.878	52.937	52.995	53.053	53.112	53.170
1.58	53.228	53.286	53.344	53.402	53.460	53.517	53.575	53.633	53.690	53.748
1.59	53.805	53.862	53.920	53.977	54.034	54.091	54.148	54.205	54.262	54.318
1.60	54.375	54.432	54.488	54.545	54.601	54.657	54.714	54.770	54.826	54.882
1.61	54.938	54.994	55.050	55.106	55.161	55.217	55.272	55.328	55.383	55.439
1.62	55.494	55.549	55.604	55.659	55.714	55.769	55.824	55.879	55.934	55.988
1.63	56.043	56.098	56.152	56.206	56.261	56.315	56.369	56.423	56.478	56.531
1.64	56.585	56.639	56.693	56.747	56.801	56.854	56.908	56.961	57.015	57.068
1.65	57.121	57.175	57.228	57.281	57.334	57.387	57.440	57.493	57.545	57.598
1.66	57.651	57.703	57.756	57.808	57.861	57.913	57.965	58.017	58.070	58.122
1.67	58.174	58.226	58.278	58.329	58.381	58.433	58.485	58.536	58.588	58.639
1.68	58.690	58.742	58.793	58.844	58.896	58.947	58.998	59.049	59.100	59.150
1.69	59.201	59.252	59.303	59.353	59.404	59.454	59.505	59.555	59.605	59.656
1.70	59.706	59.756	59.806	59.856	59.906	59.956	60.006	60.056	60.105	60.155
1.71	60.205	60.254	60.304	60.353	60.403	60.452	60.501	60.550	60.600	60.649
1.72	60.698	60.747	60.796	60.844	60.893	60.942	60.991	61.039	61.088	61.136
1.73	61.185	61.234	61.282	61.330	61.378	61.427	61.475	61.523	61.571	61.619
1.74	61.667	61.715	61.762	61.810	61.858	61.906	61.953	62.001	62.048	62.096
1.75	62.143	62.190	62.237	62.285	62.332	62.379	62.426	62.473	62.520	62.567
1.76	62.614	62.660	62.707	62.754	62.801	62.847	62.894	62.940	62.987	63.033
1.77	63.079	63.125	63.172	63.218	63.264	63.310	63.356	63.402	63.448	63.494
1.78	63.539	63.585	63.631	63.676	63.722	63.768	63.813	63.858	63.904	63.949
1.79	63.994	64.040	64.085	64.130	64.175	64.220	64.265	64.310	64.355	64.400
1.80	64.445	64.489	64.534	64.579	64.623	64.668	64.712	64.575	64.801	64.845
1.81	64.890	64.934	64.978	65.022	65.066	65.110	65.154	65.198	65.242	65.286
1.82	65.330	65.374	65.417	65.461	65.504	65.548	65.591	65.635	65.678	65.722
1.83	65.765	65.808	65.852	65.895	65.938	65.981	66.024	66.067	66.110	66.153
1.84	66.196	66.238	66.281	66.324	66.367	66.409	66.452	66.494	66.537	66.579
1.85	66.622									

TABLE III

SPECIFIC GRAVITIES AT $\frac{60°}{60°}$ F. $\left(\frac{15.56°}{15.56°}\text{ C.}\right)$ CORRESPONDING TO DEGREES BAUMÉ FOR LIQUIDS HEAVIER THAN WATER

Degrees Baumé	Tenths of Degrees Baumé									
	0	1	2	3	4	5	6	7	8	9
0	1.0000	1.0007	1.0014	1.0021	1.0028	1.0035	1.0042	1.0049	1.0055	1.0062
1	1.0069	1.0076	1.0083	1.0090	1.0097	1.0105	1.0112	1.0119	1.0126	1.0133
2	1.0140	1.0147	1.0154	1.0161	1.0168	1.0175	1.0183	1.0190	1.0197	1.0204
3	1.0211	1.0218	1.0226	1.0233	1.0240	1.0247	1.0255	1.0262	1.0269	1.0276
4	1.0284	1.0291	1.0298	1.0306	1.0313	1.0320	1.0328	1.0335	1.0342	1.0350
5	1.0357	1.0365	1.0372	1.0379	1.0387	1.0394	1.0402	1.0409	1.0417	1.0424
6	1.0432	1.0439	1.0447	1.0454	1.0462	1.0469	1.0477	1.0484	1.0492	1.0500
7	1.0507	1.0515	1.0522	1.0530	1.0538	1.0545	1.0553	1.0561	1.0569	1.0576
8	1.0584	1.0592	1.0599	1.0607	1.0615	1.0623	1.0630	1.0638	1.0646	1.0654
9	1.0662	1.0670	1.0677	1.0685	1.0693	1.0701	1.0709	1.0717	1.0725	1.0733
10	1.0741	1.0749	1.0757	1.0765	1.0773	1.0781	1.0789	1.0797	1.0805	1.0813
11	1.0821	1.0829	1.0837	1.0845	1.0853	1.0861	1.0870	1.0878	1.0886	1.0894
12	1.0902	1.0910	1.0919	1.0927	1.0935	1.0943	1.0952	1.0960	1.0968	1.0977
13	1.0985	1.0993	1.1002	1.1010	1.1018	1.1027	1.1035	1.1043	1.1052	1.1060
14	1.1069	1.1077	1.1086	1.1094	1.1103	1.1111	1.1120	1.1128	1.1137	1.1145
15	1.1154	1.1162	1.1171	1.1180	1.1188	1.1197	1.1206	1.1214	1.1223	1.1232
16	1.1240	1.1249	1.1258	1.1267	1.1275	1.1284	1.1293	1.1302	1.1310	1.1319
17	1.1328	1.1337	1.1346	1.1355	1.1364	1.1373	1.1381	1.1390	1.1399	1.1408
18	1.1417	1.1426	1.1435	1.1444	1.1453	1.1462	1.1472	1.1481	1.1490	1.1499
19	1.1508	1.1517	1.1526	1.1535	1.1545	1.1554	1.1563	1.1572	1.1581	1.1591
20	1.1600	1.1609	1.1619	1.1628	1.1637	1.1647	1.1656	1.1665	1.1675	1.1684
21	1.1694	1.1703	1.1712	1.1722	1.1731	1.1741	1.1750	1.1760	1.1769	1.1779
22	1.1789	1.1798	1.1808	1.1817	1.1827	1.1837	1.1846	1.1856	1.1866	1.1876
23	1.1885	1.1895	1.1905	1.1915	1.1924	1.1934	1.1944	1.1954	1.1964	1.1974
24	1.1983	1.1993	1.2003	1.2013	1.2023	1.2033	1.2043	1.2053	1.2063	1.2073
25	1.2083	1.2093	1.2104	1.2114	1.2124	1.2134	1.2144	1.2154	1.2164	1.2175
26	1.2185	1.2195	1.2205	1.2216	1.2226	1.2236	1.2247	1.2257	1.2267	1.2278
27	1.2288	1.2299	1.2309	1.2319	1.2330	1.2340	1.2351	1.2361	1.2372	1.2383
28	1.2393	1.2404	1.2414	1.2425	1.2436	1.2446	1.2457	1.2468	1.2478	1.2489
29	1.2500	1.2511	1.2522	1.2532	1.2543	1.2554	1.2565	1.2576	1.2587	1.2598
30	1.2609	1.2620	1.2631	1.2642	1.2653	1.2664	1.2675	1.2686	1.2697	1.2708
31	1.2719	1.2730	1.2742	1.2753	1.2764	1.2775	1.2787	1.2798	1.2809	1.2821
32	1.2832	1.2843	1.2855	1.2866	1.2877	1.2889	1.2900	1.2912	1.2923	1.2935
33	1.2946	1.2958	1.2970	1.2981	1.2993	1.3004	1.3016	1.3028	1.3040	1.3051
34	1.3063	1.3075	1.3087	1.3098	1.3110	1.3122	1.3134	1.3146	1.3158	1.3170
35	1.3182	1.3194	1.3206	1.3218	1.3230	1.3242	1.3254	1.3266	1.3278	1.3291
36	1.3303	1.3315	1.3327	1.3339	1.3352	1.3364	1.3376	1.3389	1.3401	1.3414
37	1.3426	1.3438	1.3451	1.3463	1.3476	1.3488	1.3501	1.3514	1.3526	1.3539
38	1.3551	1 3564	1.3577	1.3590	1.3602	1.3615	1.3628	1.3641	1.3653	1.3666
39	1.3679	1.3692	1.3705	1.3718	1.3731	1.3744	1.3757	1.3770	1.3783	1.3796
40	1.3810	1.3823	1.3836	1.3849	1.3862	1.3876	1.3889	1.3902	1.3916	1.3929
41	1.3942	1.3956	1.3969	1.3983	1.3996	1.4010	1.4023	1.4037	1.4050	1.4064
42	1.4078	1.4091	1.4105	1.4119	1.4133	1.4146	1.4160	1.4174	1.4188	1.4202
43	1.4216	1.4230	1.4244	1.4258	1.4272	1.4286	1.4300	1.4314	1.4328	1.4342
44	1.4356	1.4371	1.4385	1.4399	1.4414	1.4428	1.4442	1.4457	1.4471	1.4486
45	1.4500	1.4515	1.4529	1.4544	1.4558	1.4573	1.4588	1.4602	1.4617	1.4632
46	1.4646	1.4661	1.4676	1.4691	1.4706	1.4721	1.4736	1.4751	1.4766	1.4781
47	1.4796	1.4811	1.4826	1.4841	1.4857	1.4872	1.4887	1.4902	1.4918	1.4933
48	1.4948	1.4964	1.4979	1.4995	1.5010	1.5026	1.5041	1.5057	1.5073	1.5088
49	1.5104	1.5120	1.5136	1.5152	1.5167	1.5183	1.5199	1.5215	1.5231	1.5247
50	1.5263	1.5279	1.5295	1.5312	1.5328	1.5344	1.5360	1.5376	1.5393	1.5409
51	1.5426	1.5442	1.5458	1.5475	1.5491	1.5508	1.5525	1.5541	1.5558	1.5575
52	1.5591	z.5008	1.5625	1.5642	1.5659	1.5676	1.5693	1.5710	1.5727	1.5744
53	1.5761	1.5778	1.5795	1.5812	1.5830	1.5847	1.5864	1.5882	1.5899	1.5917
54	1.5934	1.5952	1.5969	1.5987	1.6004	1.6022	1.6040	1.6058	1.6075	1.6093
55	1.6111	1.5129	1.6147	1.6165	1.6183	1.6201	1.6219	1.6237	1.6256	1.6274
56	1.6292	1.6310	1.6329	1.6347	1.6366	1.6384	1.6403	1.6421	1.6440	1.6459
57	1.6477	1.6496	1.6515	1.6534	1.6553	1.6571	1.6590	1.6609	1.6628	1.6648
58	1.6667	1.6686	1.6705	1.6724	1.6744	1.6763	1.6782	1.6802	1.6821	1.6841
59	1.6860	1.6880	1.6900	1.6919	1.6939	1.6959	1.6979	1.6999	1.7019	1.7039
60	1.7059	1.7079	1.7099	1.7119	1.7139	1.7160	1.7180	1.7200	1.7221	1.7241
61	1.7262	1.7282	1.7303	1.7324	1.7344	1.7365	1.7386	1.7407	1.7428	1.7449
62	1.7470	1.7491	1.7512	1.7533	1.7554	1.7576	1.7597	1.7618	1.7640	1.7661
63	1.7683	1.7705	1.7726	1.7748	1.7770	1.7791	1.7813	1.7835	1.7857	1.7879
64	1.7901	1.7923	1.7946	1.7968	1.7990	1.8012	1.8035	1.8057	1.8080	1.8102
65	1.8125	1.8148	1.8170	1.8193	1.8216	1.8239	1.8262	1.8285	1.8308	1.8331
66	1.8354	1.8378	1.8401	1.8424	1.8448	1.8471	1.8495	1.8519	1.8542	1.8566
67	1.8590	1.8614	1.8638	1.8662	1.8686	1.8710	1.8734	1.8758	1.8782	1.8807
68	1.8831	1.8856	1.8880	1.8905	1.8930	1.8954	1.8979	1.9004	1.9029	1.9054
69	1.9079	1.9104	1.9129	1.9155	1.9180	1.9205	1.9231	1.9256	1.9282	1.9308
70	1.9333									

TABLE IV

DEGREES BAUMÉ CORRESPONDING TO SPECIFIC GRAVITIES AT $\frac{60°}{60°}$ F. $\left(\frac{15.56°}{15.56°}\text{ C.}\right)$ FOR LIQUIDS LIGHTER THAN WATER

Sp. Gr. $\frac{15.56°}{15.56°}$ Cent.	0	1	2	3	4	5	6	7	8	9
0.60	103.333	102.945	102.558	102.172	101.788	101.405	101.023	100.642	100.263	99.885
.61	99.508	99.133	98.758	98.385	98.013	97.642	97.273	96.904	96.537	96.171
.62	95.806	95.443	95.080	94.719	94.359	94.000	93.642	93.285	92.930	92.576
.63	92.222	91.870	91.519	91.169	90.820	90.472	90.126	89.780	89.436	89.092
.64	88.750	88.409	88.068	87.729	87.391	87.054	86.718	86.383	86.049	85.716
.65	85.385	85.054	84.724	84.395	84.067	83.741	83.415	83.090	82.766	82.443
.66	82.121	81.800	81.480	81.161	80.843	80.526	80.210	79.895	79.581	79.268
.67	78.955	78.644	78.333	78.024	77.715	77.407	77.101	76.795	76.490	76.186
.68	75.882	75.580	75.279	74.978	74.678	74.380	74.082	73.785	73.488	73.193
.69	72.899	72.605	72.312	72.020	71.729	71.439	71.149	70.861	70.573	70.286
.70	70.000	69.715	69.430	69.146	68.864	68.582	68.300	68.020	67.740	67.461
.71	67.183	66.906	66.629	66.354	66.078	65.804	65.531	65.258	64.986	64.715
.72	64.444	64.175	63.906	63.638	63.370	63.103	62.837	62.572	62.308	62.044
.73	61.781	61.518	61.257	60.996	60.736	60.476	60.217	59.959	59.702	59.445
.74	59.189	58.934	58.679	58.425	58.172	57.919	57.668	57.416	57.166	56.916
.75	56.667	56.418	56.170	55.923	55.676	55.430	55.185	54.941	54.697	54.453
.76	54.210	53.968	53.727	53.486	53.246	53.007	52.768	52.529	52.292	52.055
.77	51.818	51.582	51.347	51.113	50.879	50.645	50.412	50.180	49.949	49.718
.78	49.487	49.257	49.028	48.799	48.571	48.344	48.117	47.891	47.665	47.440
.79	47.215	46.991	46.768	46.545	46.322	46.101	45.879	45.659	45.439	45.219
.80	45.000	44.781	44.564	44.346	44.129	43.913	43.697	43.482	43.267	43.053
.81	42.840	42.626	42.414	42.202	41.990	41.779	41.569	41.359	41.149	40.940
.82	40.732	40.524	40.316	40.109	39.903	39.697	39.492	39.287	39.082	38.878
.83	38.675	38.472	38.269	38.067	37.866	37.665	37.464	37.264	37.064	36.866
.84	36.667	36.469	36.271	36.074	35.877	35.680	35.485	35.289	35.094	34.900
.85	34.706	34.512	34.319	34.127	33.934	33.743	33.551	33.361	33.170	32.980
.86	32.791	32.602	32.413	32.225	32.037	31.850	31.663	31.476	31.290	31.105
.87	30.920	30.735	30.550	30.366	30.183	30.000	29.817	29.635	29.453	29.272
.88	29.091	28.910	28.730	28.550	28.371	28.192	28.014	27.835	27.658	27.480
.89	27.303	27.127	26.951	26.775	26.600	26.425	26.250	26.076	25.902	25.729
.90	25.556	25.383	25.211	25.039	24.867	24.696	24.525	24.355	24.185	24.015
.91	23.846	23.677	23.509	23.341	23.173	23.005	22.838	22.672	22.506	22.339
.92	22.174	22.009	21.844	21.679	21.515	21.351	21.188	21.025	20.862	20.700
.93	20.538	20.376	20.215	20.054	19.893	19.733	19.573	19.413	19.254	19.095
.94	18.936	18.778	18.620	18.462	18.305	18.148	17.991	17.835	17.679	17.524
.95	17.368	17.214	17.059	16.905	16.751	16.597	16.444	16.290	16.138	15.985
.96	15.833	15.682	15.530	15.379	15.228	15.078	14.928	14.778	14.628	14.479
.97	14.330	14.181	14.033	13.885	13.737	13.590	13.443	13.297	13.149	13.003
.98	12.857	12.712	12.566	12.421	12.276	12.132	11.988	11.844	11.700	11.557
.99	11.414	11.271	11.129	10.987	10.845	10.704	10.562	10.421	10.281	10.140
1.00	10.000									

TABLE V

SPECIFIC GRAVITIES AT $\frac{60°}{60°}$ F. $\left(\frac{15.56°}{15.56°} \text{ C.}\right)$ CORRESPONDING TO DEGREES BAUMÉ FOR LIQUIDS LIGHTER THAN WATER

Degrees Baumé	Tenths of Degrees Baumé									
	0	1	2	3	4	5	6	7	8	9
10	1.0000	0.9993	0.9986	0.9979	0.9972	0.9964	0.9957	0.9950	0.9943	0.9936
11	.9929	.9922	.9915	.9908	.9901	.9894	.9887	.9880	.9873	.9866
12	.9859	.9852	.9845	.9838	.9831	.9825	.9818	.9811	.9804	.9797
13	.9790	.9783	.9777	.9770	.9763	.9756	.9749	.9743	.9736	.9729
14	.9722	.9715	.9709	.9702	.9695	.9689	.9682	.9675	.9669	.9662
15	.9655	.9649	.9642	.9635	.9629	.9622	.9615	.9609	.9602	.9596
16	.9589	.9582	.9576	.9569	.9563	.9556	.9550	.9543	.9537	.9530
17	.9524	.9517	.9511	.9504	.9498	.9492	.9485	.9479	.9472	.9466
18	.9459	.9453	.9447	.9440	.9434	.9428	.9421	.9415	.9409	.9402
19	.9396	.9390	.9383	.9377	.9371	.9365	.9358	.9352	.9346	.9340
20	.9333	.9327	.9321	.9315	.9309	.9302	.9296	.9290	.9284	.9278
21	.9272	.9265	.9259	.9253	.9247	.9241	.9235	.9229	.9223	.9217
22	.9211	.9204	.9198	.9192	.9186	.9180	.9174	.9168	.9162	.9156
23	.9150	.9144	.9138	.9132	.9126	.9121	.9115	.9109	.9103	.9097
24	.9091	.9085	.9079	.9073	.9067	.9061	.9056	.9050	.9044	.9038
25	.9032	.9026	.9021	.9015	.9009	.9003	.8997	.8992	.8986	.8980
26	.8974	.8969	.8963	.8957	.8951	.8946	.8940	.8934	.8929	.8923
27	.8917	.8912	.8906	.8900	.8895	.8889	.8883	.8878	.8872	.8866
28	.8861	.8855	.8850	.8844	.8838	.8833	.8827	.8822	.8816	.8811
29	.8805	.8799	.8794	.8788	.8783	.8777	.8772	.8766	.8761	.8755
30	.8750	.8745	.8739	.8734	.8728	.8723	.8717	.8712	.8706	.8701
31	.8696	.8690	.8685	.8679	.8674	.8669	.8663	.8658	.8653	.8647
32	.8642	.8637	.8631	.8626	.8621	.8615	.8610	.8605	.8600	.8594
33	.8589	.8584	.8578	.8573	.8568	.8563	.8557	.8552	.8547	.8542
34	.8537	.8531	.8526	.8521	.8516	.8511	.8505	.8500	.8495	.8490
35	.8485	.8480	.8475	.8469	.8464	.8459	.8454	.8449	.8444	.8439
36	.8434	.8429	.8424	.8419	.8413	.8408	.8403	.8398	.8393	.8388
37	.8383	.8378	.8373	.8368	.8363	.8358	.8353	.8348	.8343	.8338
38	.8333	.8328	.8323	.8318	.8314	.8309	.8304	.8299	.8294	.8289
39	.8284	.8279	.8274	.8269	.8264	.8260	.8255	.8250	.8245	.8240
40	.8235	.8230	.8226	.8221	.8216	.8211	.8206	.8202	.8197	.8192
41	.8187	.8182	.8178	.8173	.8168	.8163	.8159	.8154	.8149	.8144
42	.8140	.8135	.8130	.8125	.8121	.8116	.8111	.8107	.8102	.8097
43	.8092	.8088	.8083	.8078	.8074	.8069	.8065	.8060	.8055	.8051
44	.8046	.8041	.8037	.8032	.8028	.8023	.8018	.8014	.8009	.8005
45	.8000	.7995	.7991	.7986	.7982	.7977	.7973	.7968	.7964	.7959
46	.7955	.7950	.7946	.7941	.7937	.7932	.7928	.7923	.7919	.7914
47	.7910	.7905	.7901	.7896	.7892	.7887	.7883	.7878	.7874	.7870
48	.7865	.7861	.7856	.7852	.7848	.7843	.7839	.7834	.7830	.7826
49	.7821	.7817	.7812	.7808	.7804	.7799	.7795	.7791	.7786	.7782
50	.7778	.7773	.7769	.7765	.7761	.7756	.7752	.7748	.7743	.7739
51	.7735	.7731	.7726	.7722	.7718	.7713	.7709	.7705	.7701	.7697
52	.7692	.7688	.7684	.7680	.7675	.7671	.7667	.7663	.7659	.7654
53	.7650	.7646	.7642	.7638	.7634	.7629	.7625	.7621	.7617	.7613
54	.7609	.7605	.7600	.7596	.7592	.7588	.7584	.7580	.7576	.7572

TABLE V—(*Continued*)

SPECIFIC GRAVITIES AT $\frac{60°}{60°}$ F. $\left(\frac{15.56°}{15.56°}\text{ C.}\right)$ CORRESPONDING TO DEGREES BAUMÉ FOR LIQUIDS LIGHTER THAN WATER

Degrees Baumé	Tenths of Degrees Baumé									
	0	1	2	3	4	5	6	7	8	9
55	0.7568	0.7563	0.7559	0.7555	0.7551	0.7547	0.7543	0.7539	0.7535	0.7531
56	.7527	.7523	.7519	.7515	.7511	.7507	.7503	.7499	.7495	.7491
57	.7487	.7483	.7479	.7475	.7471	.7467	.7463	.7459	.7455	.7451
58	.7447	.7443	.7439	.7435	.7431	.7427	.7423	.7419	.7415	.7411
59	.7407	.7403	.7400	.7396	.7392	.7388	.7384	.7380	.7376	.7372
60	.7368	.7365	.7361	.7357	.7353	.7349	.7345	.7341	.7338	.7334
61	.7330	.7326	.7322	.7318	.7315	.7311	.7307	.7303	.7299	.7295
62	.7292	.7288	.7284	.7280	.7277	.7273	.7269	.7265	.7261	.7258
63	.7254	.7250	.7246	.7243	.7239	.7235	.7231	.7228	.7224	.7220
64	.7216	.7213	.7209	.7205	.7202	.7198	.7194	.7191	.7187	.7183
65	.7179	.7176	.7172	.7168	.7165	.7161	.7157	.7154	.7150	.7147
66	.7143	.7139	.7136	.7132	.7128	.7125	.7121	.7117	.7114	.7110
67	.7107	.7103	.7099	.7096	.7092	.7089	.7085	.7081	.7078	.7074
68	.7071	.7067	.7064	.7060	.7056	.7053	.7049	.7046	.7042	.7039
69	.7035	.7032	.7028	.7025	.7021	.7018	.7014	.7011	.7007	.7004
70	.7000	.6997	.6993	.6990	.6986	.6983	.6979	.6976	.6972	.6969
71	.6965	.6962	.6958	.6955	.6951	.6948	.6944	.6941	.6938	.6934
72	.6931	.6927	.6924	.6920	.6917	.6914	.6910	.6907	.6903	.6900
73	.6897	.6893	.6890	.6886	.6883	.6880	.6876	.6873	.6869	.6866
74	.6863	.6859	.6856	.6853	.6849	.6846	.6843	.6839	.6836	.6833
75	.6829	.6826	.6823	.6819	.6816	.6813	.6809	.6806	.6803	.6799
76	.6796	.6793	.6790	.6786	.6783	.6780	.6776	.6773	.6770	.6767
77	.6763	.6760	.6757	.6753	.6750	.6747	.6744	.6740	.6737	.6734
78	.6731	.6728	.6724	.6721	.6718	.6715	.6711	.6708	.6705	.6702
79	.6699	.6695	.6692	.6689	.6686	.6683	.6679	.6676	.6673	.6670
80	.6667	.6663	.6660	.6657	.6654	.6651	.6648	.6645	.6641	.6638
81	.6635	.6632	.6629	.6626	.6623	.6619	.6616	.6613	.6610	.6607
82	.6604	.6601	.6598	.6594	.6591	.6588	.6585	.6582	.6579	.6576
83	.6573	.6570	.6567	.6564	.6560	.6557	.6554	.6551	.6548	.6545
84	.6542	.6539	.6536	.6533	.6530	.6527	.6524	.6521	.6518	.6515
85	.6512	.6509	.6506	.6503	.6500	.6497	.6494	.6490	.6487	.6484
86	.6482	.6479	.6476	.6473	.6470	.6467	.6464	.6461	.6458	.6455
87	.6452	.6449	.6446	.6443	.6440	.6437	.6434	.6431	.6428	.6425
88	.6422	.6419	.6416	.6413	.6410	.6407	.6404	.6401	.6399	.6396
89	.6393	.6390	.6387	.6384	.6381	.6378	.6375	.6372	.6369	.6367
90	.6364	.6361	.6358	.6355	.6352	.6349	.6346	.6343	.6341	.6338
91	.6335	.6332	.6329	.6326	.6323	.6321	.6318	.6315	.6312	.6309
92	.6306	.6303	.6301	.6298	.6295	.6292	.6289	.6286	.6284	.6281
93	.6278	.6275	.6272	.6270	.6267	.6264	.6261	.6258	.6256	.6253
94	.6250	.6247	.6244	.6242	.6239	.6236	.6233	.6231	.6228	.6225
95	.6222	.6219	.6217	.6214	.6211	.6208	.6206	.6203	.6200	.6197
96	.6195	.6192	.6189	.6186	.6184	.6181	.6178	.6176	.6173	.6170
97	.6167	.6165	.6162	.6159	.6157	.6154	.6151	.6148	.6146	.6143
98	.6140	.6138	.6135	.6132	.6130	.6127	.6124	.6122	.6119	.6116
99	.6114	.6111	.6108	.6106	.6103	.6100	.6098	.6095	.6092	.6090
100	.6087									

is 1.419; then the corresponding degrees Baumé will be found in column 9, in the horizontal line beginning with 1.41, and is 42.815. Thus, a specific gravity of 1.846 corresponds to 66.452° Bé., the last figure of the specific gravity being obtained from the column headed by the figure 6 and then by reading down column 6, until the horizontal line beginning with 1.84 is reached, at which point the figure 66.452 is obtained. The figures used for purposes of illustration are underlined in the table. Specific gravities are given to three decimal places in Table II, and in commercial work greater accuracy than this is seldom necessary.

In Table III, 10° Bé. corresponds to a specific gravity of 1.0741, and 10.5° Bé. corresponds to a specific gravity of 1,0781, which is found at the point where column 5 meets the horizontal line beginning with 10° Bé. The figures are underlined in the table.

The explanations given for Tables II and III will suffice also for the use of Tables IV and V.

29. A.P.I. and Specific Gravity.—The A.P.I. (American Petroleum Institute) gravity is used instead of degrees Baumé in oil-plant practice. The specific gravity of oil is always given at 60° F., referred to water at 60° F. Unless otherwise stated, the A.P.I. gravity or specific gravity refers to these constants at 60° F. The specific gravity of crude petroleum oils depends on the source and nature of the oil. The values lie between 0.735 and 0.950. However, exceptionally light and very heavy oils have been found with specific gravities of 0.650 and 1.060. The differences may be attributed to the predominance of one class of hydrocarbons and to the presence of varying amounts of heavy asphaltic matter.

Up until 1921 the specific gravity of crude petroleum oils was expressed by the use of the Baumé scale and referred to as the Baumé gravity. The equation that was used to show the relation between the specific gravity and the Baumé gravity of petroleum oil products was

$$\text{Degrees Baumé} = \frac{140}{\text{Sp. Gr. } 60°/60° \text{ F.}} - 130$$

Probably through some error, a new Baumé scale came into use based on the equation

$$\text{Degrees Baumé} = \frac{141.5}{\text{Sp. Gr. } 60°/60° \text{ F.}} - 131.5$$

In order to avoid confusion, this new scale was named the A.P.I. scale and was recommended for use in the petroleum industry. The relation between the specific gravity and the A.P.I. gravity is shown by the following equations:

$$\text{A.P.I.} = \frac{141.5}{\text{Sp. Gr.}} - 131.5$$

$$\text{Specific gravity} = \frac{141.5}{\text{A.P.I.} + 131.5}$$

The A.P.I. gravity is used extensively as an indication of the quality of crude petroleum and, for any particular class of oils, will serve as an approximately true index of the proportion of volatile constituents.

COLLOIDS

30. General Remarks.—The chemistry of colloids is very closely related to the problems of agriculture, lubrication, concentrating ores, tanning, baking, washing, cooking, photography, water purification, and sewage disposal. A knowledge of colloid chemistry is very important in the manufacturing of rubber articles, enamels, paints, varnishes, cements, glass, porcelain, alloys, dairy products, glues, gelatin, gas masks, soap, oils, inks, and crayons.

Colloid chemistry may be defined as the chemistry of dispersed grains, drops, and bubbles of a substance in some other substance. By grains is meant small solid particles; drops are small liquid particles; and bubbles are small gas particles.

In order that the grains, drops, and bubbles enter into the realm of colloid chemistry, they must be sufficiently small. The diameters of these substances must range from 1 mμ to 100 mμ (1 millimicron, 1 mμ, is one-millionth of a millimeter). The largest molecules approach a diameter of 1 mμ, and the smallest particle that is visible with the aid of a very good

microscope is about 100 mμ in diameter. Therefore, the realm of colloid chemistry ranges from the upper limit of molecular dimensions to the lower limit of microscopic visibility.

Most colloidal particles are aggregates of hundreds or thousands of molecules. When these colloidal particles coalesce into larger aggregates, they may be precipitated from suspension.

It may be conveniently stated that acids, bases, salts, sugars, and all crystalline substances can be molecularly dispersed in water to form a true solution, while glues, gums, resins, cellulose, rubber, starch, and non-crystalline substances form colloids; that is, the dispersed particles are much larger than molecules.

31. Dispersions.—Dispersion is the process of scattering material that has been subdivided into smaller and smaller particles through a second material. Milk is a dispersion of small particles of casein and butterfat in a water solution of sugar and salts. The dispersed material is called the *disperse phase* or *inner phase*, while the material in which the dispersion takes place is known as the *dispersion medium* or *outer phase*.

When the dispersed material is subdivided into molecules and scattered throughout the dispersion medium, a solution is obtained. This is what happens when acids, bases, and salts are placed in water. On the other hand, soap and glue are not completely dispersed by water. Even though the dispersed particles are smaller than microscopic size, they are nevertheless enormous when compared with the molecules of acids, bases, and salts. The dispersion of soap or glue in water is known as a *colloidal dispersion* or *sol* (often referred to as a colloidal solution). A suspension of clay in water represents a less complete dispersion, since the dispersed particles in this case are easily visible by means of the microscope and sometimes to the naked eye. The different classes of dispersions in Table VI are classified according to the diameters of the dispersed particles.

32. Types of Dispersions.—A dispersion may be formed by dispersing or scattering a solid, liquid, or gas in a solid, liquid, or gas. However, the dispersion of a gas with a gas will always result in a true solution, since the dispersed particles are

TABLE VI

CLASSES OF DISPERSIONS

Solutions	Colloidal Dispersions	Fine Dispersions	Coarse Dispersions
Diameter, 0.1 to 1 mμ	Diameter, 1 to 100 mμ	Diameter, 100 to 50,000 mμ	Diameter, 50,000 mμ or over
Dispersed particles are molecules or ions.	Dispersed particles are below microscopic size.	Dispersed particles are visible under microscope.	Dispersed particles are visible to the naked eye.

the individual molecules of the respective gases involved. In the remaining types of dispersions, the dispersed particles may be of colloidal dimensions (1 to 100 mμ), of microscopic size, or visible to the naked eye.

The following are examples of the different types of dispersions:

A solid dispersed in a solid; gold in ruby glass.

A solid dispersed in a liquid; india ink (this type of dispersion is known as a suspension).

A solid dispersed in a gas; smoke.

A liquid dispersed in a solid; cheese.

A liquid dispersed in a liquid; milk or butter (dispersions of this kind are called emulsions).

A liquid dispersed in a gas; fog, mist, or steam.

A gas dispersed in a solid; pumice stone.

A gas dispersed in a liquid; whipped cream (dispersions of this type are called foams).

33. Tyndall Test.—Colloidal dispersions may appear as true solutions, that is, they may be clear and transparent. However, they may be recognized as collodial dispersions by the Tyndall test. The Tyndall test consists in passing a beam of light through the dispersion as indicated in Fig. 2. The path of the beam of light becomes illuminated, since each colloidal particle reflects a portion of the light toward the observer. Under similar conditions, a true solution will not show a path

87760

of a similar beam of light, because the molecules of the solute are too small to reflect light.

34. Preparation of Colloidal Dispersions.—There are several methods whereby the common insoluble substances may become colloidally suspended. Some methods are chemical, and others are purely mechanical. It must be remembered that, even though these suspensions may appear as true solutions to the naked eye, they are not true solutions. The effect of colloidally

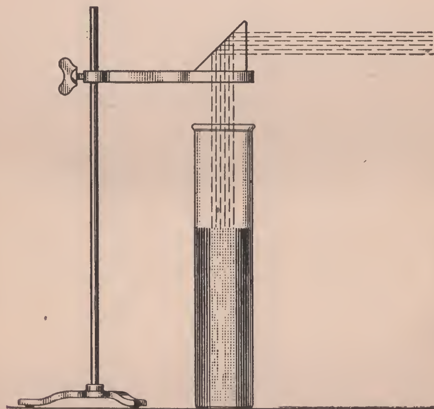


FIG. 2

suspended material on freezing-point lowering, boiling-point rise, and vapor pressure is trivial, as might be expected, since there are fewer particles per gram of suspended material as compared with the number of molecules from a gram of matter that is in a true solution. Colloid particles or aggregates are hundreds or thousands of times as large as a molecule of substance in a true solution.

A reaction between molecules of dissolved substances may yield colloidal aggregates. In this case colloidal suspensions are formed by the condensation of small particles (molecules) into large particles. The exact opposite of the condensation method is the dispersion method, which is the breaking down of larger particles into small particles.

35. Dispersion Methods.—A solid may be reduced to colloidal dimensions by simple grinding in the presence of a suitable dispersion medium. Sometimes a peptizing agent or protective colloid is added. A *peptizing agent* is a substance that assists in the process of dispersion by coating the dispersed particles, thereby preventing them from combining to form larger particles. India ink is a colloidal dispersion of lampblack in water in the presence of gum arabic. The gum arabic acts as a peptizing agent and prevents the coagulation of the particles of lampblack.

Certain substances are readily peptized by the mere presence of a dispersion medium. Water has long been used as a peptizing agent for glue, gelatin, agar, and other substances. The glue, gelatin, or agar is not dissolved in the sense of molecular dispersion, but only colloidally dispersed. Hot water has a more rapid peptizing action than cold.

Colloid particles or aggregates have a tendency to absorb other substances, even ions, and to hold them to their surfaces. A given surface may have a preference for certain ions, which may result in the acquisition of a positive charge by absorbing and holding a positive ion, charge and all. In like manner, another type of colloid may choose to acquire a negative ion and charge. Colloidal dispersions prepared by the absorption of ions are stable, since the like charges on the particles cause the particles to repel one another.

36. Condensation Method.—In the preparation of colloidal dispersions by the condensation method, the molecules coalesce or unite to build up particles of colloidal dimensions. Colloidal dispersions of gold, silver, mercury, platinum, and palladium in water may be prepared by striking an electric arc between electrodes of the metal involved, beneath the surface of the liquid. The electric arc causes the metal to vaporize and the vapor condenses to form particles that are of colloidal dimensions. This is a combination of dispersion followed by condensation. When colloidal dispersions of these metals are prepared, some substance must be present in the water that will coat over the colloidal particles and prevent them from coalescing to form a precipitate.

37. Suspensoids.—Many colloidal dispensions are very readily precipitated by an electrolyte (acid, base, or salt). The materials that form such colloidal dispersions are called suspensoids. Some examples of a suspensoid state are found in colloidal gold, silver, arsenic sulfide, and ferric hydroxide. These materials are very easily precipitated by a slight trace of an acid, a base, or a salt.

To illustrate, prepare some colloidal ferric hydroxide by adding a few drops of ferric chloride solution to boiling water in a small beaker. Continue boiling until the liquid becomes red. The red color indicates that colloidal ferric hydroxide is formed. Divide the colloidal ferric hydroxide dispersion into two equal parts. Add a few drops of dilute sulfuric acid to one of the parts. Immediately, the colloidal particles coagulate to form a reddish brown flocculent precipitate. A *flocculent precipitate* is a precipitate that remains suspended in a liquid as a loose, cloudlike mass.

Suspensoid particles are electrically charged. These particles are precipitated by ions with an opposite charge. Ions that have a valence of 2 are more effective than those that have a valence of 1 in causing precipitation, and the ions that have a valence of 3 are even more effective. It is the sulfate ion (SO_4^{--}) with a negative valence of 2, formed by the sulfuric acid, which causes the positively charged particles of the colloidal ferric hydroxide to precipitate. In like manner the calcium (Ca^{++}) or aluminum (Al^{+++}) ions will precipitate the negatively charged particles of colloidal arsenious sulfide.

38. Emulsoids.—Many colloidal dispersions are not easily precipitated by an electrolyte. Examples are found in colloidal dispersions of egg albumen, casein, glue, gelatin, agar, starch paste, and soaps in water. Some of these are very viscous and stable and many of them form jellies when cooled to room temperature or when the dispersion medium is altered. Such is the case of a 1 per cent suspension of agar in water. Substances which form such stable, viscous, jelly-forming colloidal dispersions are called emulsoids. The main difference between an emulsoid and a suspensoid is that the emulsoid particles

absorb water, with the result that they become swollen and semifluid.

When emulsoid colloids, such as gelatin or gluten, or colloidal plant material, such as dried fruits or seeds, are placed in water, a very noticeable swelling takes place. The degree of swelling varies greatly with the chemical nature of the colloid, and depends on the degree of acidity or alkalinity and also on the temperature of the solution.

39. Emulsoid particles do not have any definite electric charge. They may be charged either negatively or positively. In many cases the charge on the emulsoid particles depends on the reaction between the emulsoid and the dispersion medium. If the emulsoid reacts as an acid it becomes negatively charged, because it yields protons, H^+, to the dispersion medium; but if it reacts as a base it becomes positively charged, because it accepts the protons from the dispersion medium.

Emulsoid particles will very readily yield protons when surrounded by an alkaline medium, with the result that they are left with a negative charge; and they will also gain protons very easily when surrounded by an acid medium, with the result that they become positively charged.

Emulsoids that can readily yield or gain protons, depending on the acidity or alkalinity of the dispersion medium, are called *amphoteric emulsoids*. For all the amphoteric emulsoids there is a definite degree of acidity or alkalinity of the dispersion medium at which the emulsoid will act neutral. At this point the emulsoid particles lose their charge and are precipitated. The pH (degree of acidity or alkalinity) at which precipitation takes place is called the *isoelectric point* of the colloid.

40. Dialysis.—Dialysis is the separation of two substances in solution by diffusion of one of them through a membrane. The substances that commonly diffuse through the membrane in dialysis are crystalloids, and the substances that fail to pass through the membrane are colloids. However, there have been instances where colloidal substances diffused very slowly through a membrane, apparently by dissolving in the membrane.

To illustrate, hang a water-permeable cellophane tube partly filled with water in a beaker containing a solution of the salt sodium chloride (a crystalloid) and starch (a colloid). Within a few minutes, some of the dissolved salt will have diffused through the cellophane tube. The salt may be detected in the water within the cellophane tube by adding a few drops of silver nitrate solution, which will form a white precipitate of silver chloride. However, the starch will not pass through the membrane for many hours. The presence of starch can be detected by adding a few drops of iodine solution, which will color the starch blue.

Many membranes such as parchment paper, egg skin, bladder, and intestine are permeable to water and ions, but not to colloidal particles. Since ions of opposite charge cause colloidal particles to coagulate, they must be removed if the colloid is to be stable. These ions are removed by dialysis.

41. Coagulation.—Colloidal suspensions coagulate when the cause of their stability is removed. When the colloidal particles coalesce and become large aggregates, they form a precipitate. Coagulation of colloid particles will take place when the protective film is destroyed. However, the method generally used for the coagulation of suspensoids is by the addition of ions with an opposite charge.

Colloidal particles are charged electrically. In many cases all the colloidal particles are positively charged; in the other cases they are all negatively charged. These charges are due to the ions absorbed by the colloid particles. If an ion with an opposite charge is absorbed, the charges are neutralized, with the result that the neutral colloidal particles form a precipitate. The addition of bivalent ions has a much more effective precipitating power than the addition of monovalent ions, while the trivalent ions have a still more effective precipitating power than the bivalent ions.

A rapid addition of a precipitating salt may carry the colloidal suspension beyond its precipitating point, with the result that it receives an opposite charge with a certain degree of stability.

42. Protective Colloids.—The precipitation of relatively unstable colloids is prevented by the addition of small amounts of another colloidal substance. Gelatin is a protective colloid. It forms a film around the separate particles of a colloid, preventing them from touching each other and from coalescing. Colloidal gold when dispersed in the presence of gelatin is much more stable than without gelatin. In fact, the colloidal gold particles, when covered by films of gelatin, act as if they were solid particles of gelatin.

The protective colloid is also called an emulsifying agent. Casein acts as an emulsifying agent in milk. It keeps a considerable amount of butter fat in solution. The protective colloids act because they cling to the colloids, forming a protective film around the individual particles. All the protective colloids are organic compounds.

43. Gels.—Many colloidal dispersions, on cooling or on concentration by evaporation, frequently form semisolid jellies, which are called gels. These gels may contain as much as 98 per cent of water and only 1 to 2 per cent of dispersed colloidal material. A very good example of a gel is shown by the behavior of gelatin, a 5 per cent solution of which forms a gel at 18° C. A 1 per cent hot gelatin solution or a 2 per cent agar solution forms a jelly on cooling.

The remarkable feature about gels is that a very small amount of colloidal material will cause the solution to become stiff and rigid. This is the reason why a small amount of gelatin will, in solution, produce a large amount of gel.

All the fruit jellies made directly from fruits are gels produced by the presence of the colloidal substance pectin, which is present in the fruit. Apples are so rich in pectin that, if a fruit lacks this constituent, apples or the white rind of citrus fruits may be added to produce gel.

44. Soaps.—The alkali salts of oleic, stearic, palmitic, and the other fatty acids are the soaps commonly used. These soaps hydrate heavily, that is, they combine with water very readily. Because of this fact, soap, although sold in solid

cakes, contains a large amount of water. However, the soaps of the unsaturated acids, such as oleic, hydrate much less than those of the saturated acids, such as stearic and palmitic. Therefore, a cake of soap made from cottonseed oil of unsaturated fats contains less water than a cake made from cottonseed oil that has been hydrogenated (saturated with hydrogen).

Genuine castile soap, a type of sodium oleate, disperses better in cold water than do soaps of saturated acids, such as sodium stearate or sodium palmitate. For this reason, castile soap cleans better at ordinary temperatures, and is preferable for toilet use. Sodium stearate and sodium palmitate make the best soaps for the hot water of laundries. The soaps of calcium, magnesium, and lead do not hydrate very well and, consequently, do not disperse so well in water. They are practically insoluble. These soaps do not have any cleaning value. Soap does not loosen or remove dirt by chemical action; its effect is due to the properties of colloids. The rubbing loosens the dirt, which is absorbed by the colloidal particles of soap.

ELECTRON THEORY

45. Introduction.—Chemists still believe that atoms of the same element have the same physical and chemical properties, and that atoms of different elements have different physical and chemical properties. They no longer believe, however, that the atom is indivisible and that it is the smallest thing in existence.

It is impressive to know that sodium and potassium form positive ions, whereas chlorine and bromine form negative ions; that these elements are chemically active, whereas helium and argon are chemically inert; and that molecules of certain elements are monatomic, whereas molecules of other elements contain two or more atoms. To determine what causes these differences between elements; what holds the atoms together when they combine to form molecules; why atoms of different elements combine to form compounds; and what the actual construction of the atom is, demands an examination of the internal structure of atoms.

A series of certain discoveries which occurred toward the end of the nineteenth century answered some of these questions and gave the chemist a new conception of the structure of matter. The astronomers discovered that the hottest stars are composed mainly of a few simple gaseous elements such as hydrogen and helium, and that the colder and older stars are composed of most of the elements that are found on the earth. Since the hottest stars contain fewer elements than are found in the colder ones, it seems logical to believe that the number of elements increase in some way as the stars grow older and become colder. Very recent discoveries have led chemists to believe that simple elements such as hydrogen and helium can combine to form heavier elements.

46. Uranium and Radium.—To determine what the internal structure of atoms may be, and how it is modified, the evidence must be considered from many different sources. The first tc be considered is that afforded by the discovery that the atoms of radioactive elements are unstable, and that they decompose into particles that can be separated and identified.

In 1896 Henri Becquerel, a French chemist, discovered that a crystal of uranium salt, when placed in a dark room near a photographic plate, would affect the plate as if it had been exposed to the sunlight. He also discovered that the rays emitted by uranium salts caused the air to become a conductor of electricity because they ionized the air. The radioactivity of every uranium compound was found to be proportional to its uranium content.

These discoveries astounded the scientific world to such a degree that the scientists began to study and investigate the properties of uranium. They discovered that the atoms of uranium explode spontaneously, ejecting positively charged *helium atoms* and negatively charged electrical particles called *electrons*. These electron particles form light rays of such an intensity when they strike an object that they are able to penetrate solid bodies.

47. At the suggestion of Becquerel, M. and Mme. Curie set out to investigate why a certain uranium compound, carnotite,

had a much greater effect than could be accounted for by its uranium content. While carrying on the investigation, the Curies discovered radium, a substance that is a million times more radioactive than uranium. They discovered that radium is one of the decomposition products of uranium. When an atom of uranium decomposes, shooting off helium atoms and electrons, the remainder of the atom becomes an atom of a different element. Radium also decomposes spontaneously, changing into helium and radon. From these discoveries it can be safely stated that some elements can change spontaneously into other elements.

Scientists have discovered methods whereby other elements can be made to undergo similar changes. By these methods they have succeeded in forming lighter elements from heavier ones, nitrogen from oxygen; and in forming heavier elements from lighter ones, carbon from beryllium. Because of these discoveries scientists no longer believe the atom to be indivisible, but that it is a compact bundle of electrically charged particles.

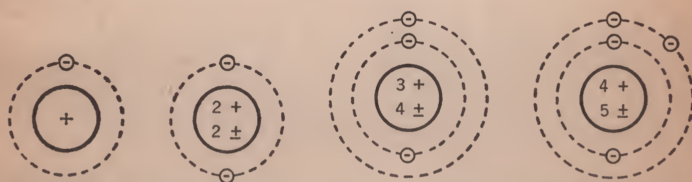
48. Atomic Nucleus.—All atoms have a central portion called *nucleus*, which has a positive charge. The nucleus is never disturbed in a chemical reaction, but is affected by radioactive decompositions.

The principal constituents of a nucleus are positively charged particles called *protons* and uncharged particles called *neutrons*. The proton is the nucleus of an ordinary hydrogen atom, having a single positive charge and a mass of 1.007; while the neutron has a mass of 1.009. The neutron is a combination of a proton and an electron. The proton is represented by a plus (+) sign; the electron by a minus (−) sign; and the neutron by a (±) sign. An electron is a negatively charged particle with a mass of $\frac{1}{1,850}$ of a proton. The charge of an electron is equal and opposite to the charge of a proton. Since the electron and proton combine to form a neutron, it follows that the neutron is an uncharged particle.

49. Electron Shells.—Even though the nucleus of every atom has a positive charge, the atom as a whole is electrically

neutral. The neutrality of the atom is due to the fact that the nucleus is surrounded by electrons, which are equal in number to the protons in the nucleus. Bohr, a Danish scientist, developed the theory that the electrons revolve around the nucleus in orbits, just as the planets of the solar system revolve around the sun. However, the scientists now believe that these electrons do not revolve in perfectly regular orbits, but in paths that are subject to continuous change.

Lewis and Langmuir developed the theory that the electrons surrounding the nucleus are arranged in successive concentric shells. Since all atoms as a whole are electrically neutral, it follows that the total number of electrons in these shells must be equal to the number of free protons in the nucleus. The



(a) Hydrogen Atom *(b)* Helium Atom *(c)* Lithium Atom *(d)* Beryllium Atom

FIG. 3

number of free protons in the nucleus is the atomic number. These shells contain a definite number of electrons. The first shell is complete when it has two electrons, the second when it has eight, the third when it has eight, the fourth when it has eighteen, the fifth when it has eighteen, the sixth when it has thirty-two, and the seventh is an incomplete shell.

50. Construction of Atoms.—Hydrogen is the lightest of all elements. It has an atomic number of 1. Since all atoms as a whole are uncharged, the hydrogen atom must have one electron in the shell surrounding its nucleus in order to neutralize the positive charge of the nucleus. The construction of the hydrogen atom is shown in Fig. 3 (*a*).

Helium, view (*b*), has an atomic number of 2. It has two protons and two neutrons in its nucleus. The atom of all the elements, except hydrogen, contains neutrons in its nucleus. Since these neutrons have no charge, they do not affect the

chemical activity of the elements. In order that the helium atom may have no charge, it must have two electrons in the shell surrounding the nucleus, which contains two protons.

Lithium, view (*c*), has an atomic number of 3. It has three protons and four neutrons in its nucleus. Since the nucleus has a (+3) charge, there must be three electrons in the shells surrounding the nucleus in order to neutralize the charge. However, since the first electron shell can contain only two electrons, the third electron must be in the second shell.

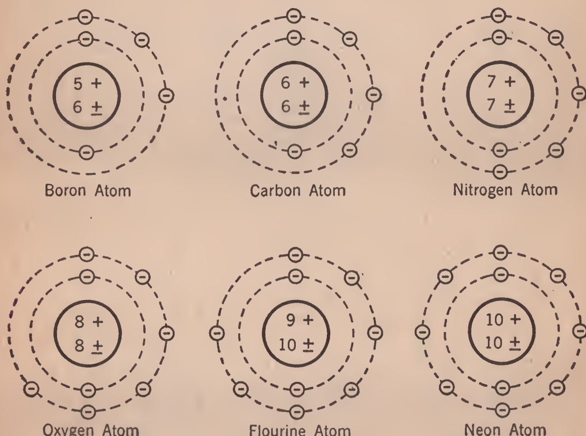


FIG. 4

Beryllium, view (*b*), has an atomic number of 4. Therefore, four electrons are required to neutralize the charge on its nucleus. Since the first shell can contain only two electrons, the third and fourth electrons must take their place in the second shell.

51. The construction of the atoms of boron, carbon, nitrogen, oxygen, fluorine, and neon are shown in Fig. 4. It is evident from the construction of these atoms that each element has one more proton in the nucleus and one more electron in the shells surrounding the nucleus than the preceding one. The neon atom has both shells completed, since the second shell can hold only eight electrons.

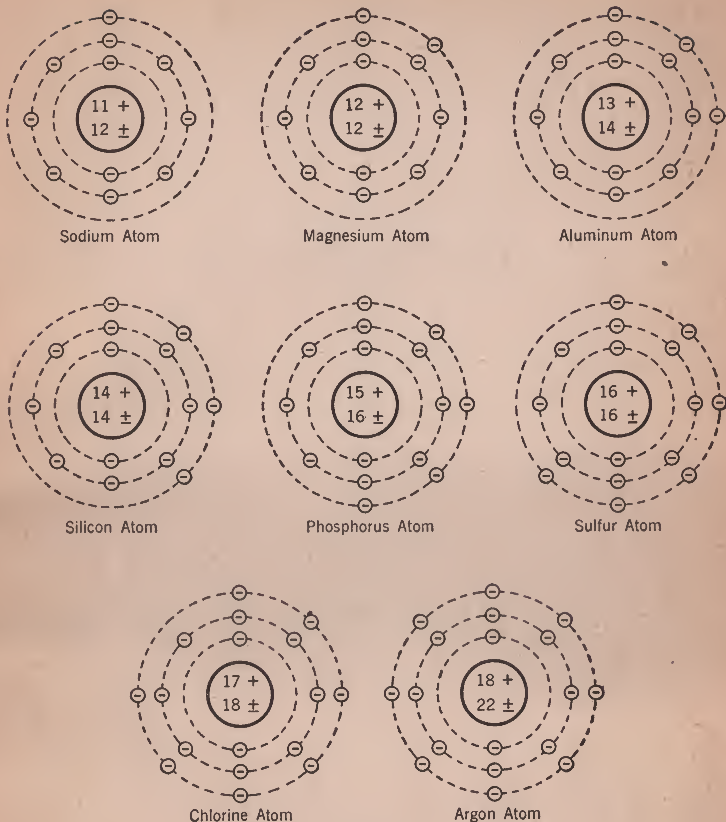

11 +
12 ±
Sodium Atom
12 +
12 ±
Magnesium Atom
13 +
14 ±
Aluminum Atom
14 +
14 ±
Silicon Atom
15 +
16 ±
Phosphorus Atom
16 +
16 ±
Sulfur Atom
17 +
18 ±
Chlorine Atom
18 +
22 ±
Argon Atom

FIG. 5

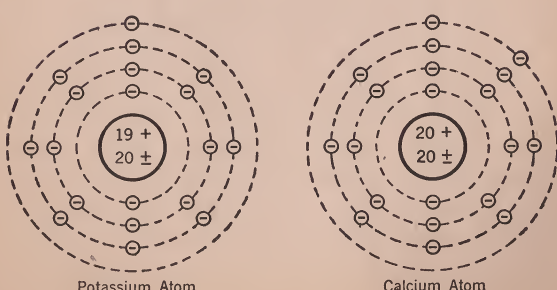

19 +
20 ±
Potassium Atom
20 +
20 ±
Calcium Atom

FIG. 6

Sodium, which is the next element beyond neon, has an atomic number of 11. Since the first shell can hold only two electrons and the second only eight, the eleventh electron must enter into a third shell. The construction of the atoms in Fig. 5 will illustrate the formation and completion of the third shell. These elements, in the order of their atomic number, are sodium, magnesium, aluminum, silicon, phosphorus, sulfur, chlorine, and argon.

The atoms of potassium and calcium, Fig. 6, illustrate the formation of the fourth shell. The potassium atom has one electron and the calcium atom has two electrons in the fourth shell. This shell will hold eighteen electrons. Before a fifth shell can begin to form, the fourth shell must be completed.

PERIODIC LAW

52. Classification of Elements.—It has long been known by chemists that there are certain elements that may be grouped together because of their similarity of properties. However, it was not until the nineteenth century that any attempt to classify them was made.

In 1816, Döbereiner, a German chemist, presented to the chemical world the discovery that similar elements occur in groups of three. Lithium, sodium, and potassium are one such triad; chlorine, bromine, and iodine constitute another; and calcium, strontium, and barium, another. If each three elements are arranged in the order of their atomic weights, it will be seen that the atomic weight of the middle element is approximately the mean of the atomic weights of the other two. For example,

$$\begin{array}{l} Li = 6.94 \\ Na = 22.97 \\ K = 39.096 \end{array} \quad \text{and} \quad \frac{6.94+39.096}{2} = 23.01$$

53. Newlands' Law of Octaves.—In 1864, Newlands put forward a more rational scheme. He arranged the elements in the order of their increasing atomic weights, exclusive of hydrogen, the lightest. In this arrangement the eighth element strongly resembles the first; the ninth, the second, etc. New-

lands' law of octaves, with the symbols of the elements concerned, is represented as follows:

Li	*Be*	*B*	*C*	*N*	*O*	*F*
Na	*Mg*	*Al*	*Si*	*P*	*S*	*Cl*
K	*Ca*					

A study of the physical and chemical properties of the elements in the same vertical column will show how closely they resemble each other. Newlands' system failed, however, mainly because, in his complete formulation, he neglected to leave space for elements that were unknown to him and have since been discovered.

54. Mendeleev's Periodic System.—Mendeleev,* a Russian chemist, presented a periodic table practically as it appears today. In 1869, he studied and compared the chemical and physical properties of the elements then known. Beginning with the lightest element, he arranged them in horizontal rows or periods and vertical columns or groups. The elements in each column had similar chemical and physical properties, and each row or period contained elements of higher atomic weights than the preceding row.

If the elements are arranged in the order of increasing atomic weights, excluding hydrogen, it will be seen that the eighth and sixteenth elements resemble each other very closely.

$$\frac{He}{4.003}\quad\frac{Li}{6.94}\quad\frac{Be}{9.02}\quad\frac{B}{10.82}\quad\frac{C}{12.01}\quad\frac{N}{14.008}\quad\frac{O}{16.00}\quad\frac{F}{19.00}$$

$$\frac{Ne}{20.183}\quad\frac{Na}{22.997}\quad\frac{Mg}{24.32}\quad\frac{Al}{26.97}\quad\frac{Si}{28.06}\quad\frac{P}{30.98}\quad\frac{S}{32.06}\quad\frac{Cl}{35.457}$$

A study of the properties of the foregoing elements will show that the similar elements reoccur at certain definite intervals. Fluorine and chlorine, for example, are both corrosive gases, and are electronegative; lithium and sodium are both silver-white metals, and are electropositive; helium and neon are gases, alike in general properties, but are neither electro-

* This is spelled according to the system for the transliteration of Russian words that has been adopted by the Americal Chemical Society. Pronounced Men-dyel-yā'-yĕf, with yā as in Yates, yĕ as in yet.

positive nor electronegative. To this classification is ascribed the old periodic law: The properties of the elements are a periodic function of the atomic weights.

55. Mendeleev's periodic classification differed from that of Newlands' in that it allowed for the undiscovered elements and that he made a subdivision of each group into two parts, *A* and *B*, where necessary. The discovery of the rare gases, helium, argon, neon, krypton, etc., after the formulation of his table, did not disturb his original classification, because he had not limited his system to any definite number of groups.

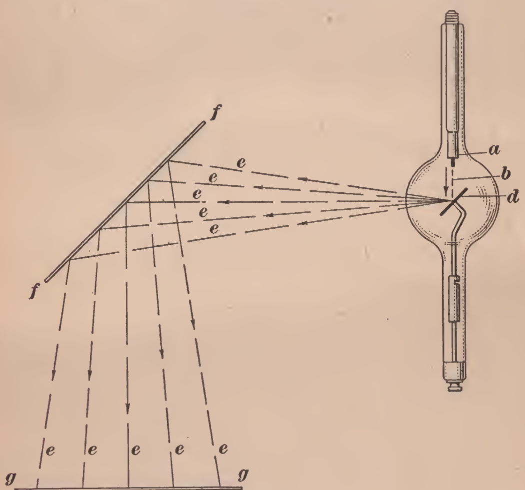


FIG. 7

After the discovery of these rare gases and other elements, certain discrepancies were noticed in his system. Argon, which precedes potassium, and tellurium, which precedes iodine, both have greater atomic weights than the elements immediately succeeding them. However, these elements were considered as exceptions to the law, since argon very obviously belongs among the rare gases and iodine among the halogens.

56. Moseley's Periodic Law.—In 1912, Moseley, a young English physicist, discovered the basis of a new periodic law

TABLE VII—PERIODIC TABLE

Groups Oxide Hydride Subgroups	I R_2O RH A	I B	II RO RH_2 A	II B	III R_2O_3 RH_3 A	III B	IV RO_2 RH_4 A	IV B	V R_2O_5 RH_3 A	V B	VI RO_3 RH_2 A	VI B	VII R_2O_7 RH A	VII B	VIII A Inert Gases	VIII B RO_4 Transition Triads		
Periods																		
1	1 *H* 1.008														2 *He* 4.003			
2	3 *Li* 6.94		4 *Be* 9.02			5 *B* 10.82		6 *C* 12.01		7 *N* 14.008		8 *O* 16.00		9 *F* 19.00	10 *Ne* 20.183			
3	11 *Na* 22.997		12 *Mg* 24.32			13 *Al* 26.97		14 *Si* 28.06		15 *P* 30.98		16 *S* 32.06		17 *Cl* 35.457	18 *A* 39.944			
4	19 *K* 39.096	29 *Cu* 63.57	20 *Ca* 40.008	30 *Zn* 65.38	21 *Sc* 45.10	31 *Ga* 69.72	22 *Ti* 47.90	32 *Ge* 72.60	23 *V* 50.95	33 *As* 74.91	24 *Cr* 52.01	34 *Se* 78.96	25 *Mn* 54.93	35 *Br* 79.916	36 *Kr* 83.7	26 *Fe* 55.85	27 *Co* 58.94	28 *Ni* 58.69
5	37 *Rb* 85.48	47 *Ag* 107.88	38 *Sr* 87.63	48 *Cd* 112.41	39 *Y* 88.92	49 *In* 114.76	40 *Zr* 91.22	50 *Sn* 118.70	41 *Cb* 92.91	51 *Sb* 121.76	42 *Mo* 95.95	52 *Te* 127.61	43 *Ma* 97.8	53 *I* 126.92	54 *Xe* 131.3	44 *Ru* 101.7	45 *Rh* 102.91	46 *Pd* 106.7
6	55 *Cs* 132.91	79 *Au* 197.2	56 *Ba* 137.36	80 *Hg* 200.61	Rare-earth elements	81 *Te* 204.39	72 *Hf* 178.6	82 *Pb* 207.21	73 *Ta* 180.88	83 *Bi* 209.00	74 *W* 183.92	84 *Po* 210.	75 *Re* 186.31	85 *Ab* 212.	86 *Rn* 222.	76 *Os* 190.2	77 *Ir* 193.1	78 *Pt* 195.23
7	87 *Vi* 223.		88 *Ra* 226.05		89 *Ac* 229.		90 *Th* 232.12		91 *Pa* 231.		92 *U* 238.07							
	57–71 Rare-earth elements		57 *La* 138.92		58 *Ce* 140.13		59 *Pr* 140.92		60 *Nd* 144.27		61 *Il* 146.		62 *Sm* 150.43		63 *Eu* 152.			
	64 *Gd* 156.9		65 *Tb* 159.2		66 *Dy* 162.46		67 *Ho* 164.94		68 *Er* 167.20		69 *Tm* 169.4		70 *Yb* 173.04		71 *Lu* 174.99			

which, unlike that of Mendeleev, has no exceptions. He discovered that there was a difference in the length of the X-rays given off by different elements when they were used as anticathodes in the X-ray tube as shown in Fig. 7. The impact of the stream of electrons *b* on the anticathode *d* causes X-rays *e* to be given off. These X-rays are reflected by a crystal *f* on to a photographic plate *g*, where the wave-length may be measured.

He discovered that, when the different elements were used as anticathodes *d*, the wave-length of X-rays decreased regularly as the atomic weights increased. However, at certain places, Moseley attained a shortening that was twice as great as he expected. He assumed that undiscovered elements would occupy these places. Science has already proved his assumptions.

Moseley numbered the elements from 1 to 92 in the order indicated by their decreasing wave-lengths. Starting with hydrogen as number 1, he gave a whole number to every element up to and including uranium.

The atomic numbers of argon and potassium place them in their correct positions. The same is true of cobalt and nickel, and of tellurium and iodine. By this means, the discrepancies that existed in the Mendeleev classification were adjusted. As a result of Moseley's work, the periodic law is now stated as follows: *The physical and chemical properties of the elements and their compounds are a periodic function of their atomic numbers.*

57. Periodic Table.—Table VII, which is similar to Mendeleev's system, but based on Moseley's law, shows a periodic classification of the elements, that is, the elements are arranged according to their atomic number. The atomic number is printed above the element and the atomic weight beneath it.

The successive horizontal rows in the table, that is, the intervals that must be passed through between similar elements, are called periods, and the vertical columns are called groups. Each period begins with a metal and ends with a rare gas.

An examination of Table VII will show that the periods are not all of the same length. It consists of (1) a period of two elements, hydrogen and helium; (2) a short period of eight elements beginning with lithium and ending with neon: (3) another short period of eight elements, beginning with sodium and ending with argon.

These short periods are followed by (4) a long period of eighteen elements, beginning with potassium and ending with krypton; and (5) another long period of eighteen elements, beginning with rubidium and ending with xenon. These long periods run through two rows of the table. In the first long period there are three elements, iron, cobalt, and nickel, which fall between the two octaves and cannot be accommodated in either. Every long period contains three such elements, which closely resemble one another. These elements are called transition triads and are placed in group *VIIIB*.

58. Next, there is (6) an extra-long period of thirty-two elements, beginning with cesium and ending with radon. In this period, however, occur the fifteen rare-earth elements, which are so similar that they are given a single place on the table. These rare-earth elements, with atomic numbers of 57 to 71, are grouped together below the periodic table.

Finally, there is (7) a period of six elements, which begins with virginium and ends with uranium. Elements with atomic numbers of 93, 94, 95, 96, and 97 have been synthesized within the last few years, which fact points to the possibility that these elements may follow uranium in the periodic table. However, these elements have not, as yet, been found to exist in nature.

In the long periods, the arrangement of the groups into subdivisions *A* and *B* shows the similarity in properties of the elements constituting each subdivision. For example, there are certain properties common to all the elements of group II; at the same time, there is a greater similarity between calcium, strontium, and barium than there is between zinc, cadmium, and mercury.

59. Periodic Table and Valence.—An examination of the periodic table will show that all the elements which occur in a

group have the same valence. The inert gases which occur in group *VIIIA* have a zero valence, since they do not combine with any element. In the table, the formulas R_2O, RO, R_2O_3, RO_2, etc., show the maximum number of atoms of oxygen which can combine with an atom of any element in the given group, and thereby reveal the maximum valence of the element of that group. The formulas RH, RH_2, RH_3, etc., show the maximum number of atoms of hydrogen which can combine with an atom of any element in a given group. This number passes from 1 to 4, then passes back to 0 with the inert gases. A property, such as valence, that rises and then falls with increasing atomic number is called a periodic property.

60. Position of Metals and Non-Metals.—The fundamental chemical division of the elements is into metals and non-metals. The metals are electropositive and the non-metals are electronegative. As the elements are traversed in the order of increasing atomic numbers, the variation of metallic and non-metallic properties is periodic.

In the two short periods from lithium to fluorine and from sodium to chlorine, there is a regular transition from great metallic and electropositive to extreme non-metallic and electronegative properties. In the period from potassium to bromine, there are two series. The first series is from potassium through manganese to the transition triad—iron, cobalt, and nickel; the second series is from copper to bromine. The elements of the first period are all metals, but show a regular decrease of electropositiveness throughout them; whereas the elements of the second series begin with the comparatively weak electropositive metal, copper, and rise in metallic strength to zinc, followed by a transition to the non-metallic and electronegative bromine. Similar transitions exist in the remaining long periods.

When the transition of properties of separate groups is considered, an increase of metallic nature or decrease of non-metallic nature is found to exist. For example, the alkali metals of group *I* increase in electropositiveness with increase of atomic number; while the halogens of group *VII* show a

decrease of electronegativeness with rise of atomic number. In the long periods, however, an opposite state of transition exists; that is, in the groups *VIII B*, *I B*, and to a certain extent *II B*, there is a decrease in electropositiveness and chemical activity with rise of atomic number. Thus, the inert metals, platinum, gold, and mercury, occur consecutively as the last members of groups *VIII B*, *I B*, and *II B*.

From all this it can be seen that in the periodic table the most active metals are in group *I*, and the most active non-metals are in group *VII;* cesium, the most electropositive metal, is in the lower left-hand corner, and fluorine, the most electronegative element, is in the upper right-hand corner.

INORGANIC CHEMISTRY

Serial 5560C (PART 3) Edition 1

EXAMINATION QUESTIONS

Notice to Students.—*Study the Instruction Paper thoroughly before you attempt to answer these questions.* **Read each question carefully and be sure you understand it;** *then write the best answer you can. When your answers are completed, examine them closely, correct all the errors you can find, and* **see that every question is answered;** *then mail your work to us.*

(1) Calculate the per cent of: (*a*) lead in $PbSO_4$; (*b*) antimony in Sb_2SO_4.

Ans. $\begin{cases} (a)\ 68.33\% \\ (b)\ 71.71\% \end{cases}$

(2) From the reaction

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$$

calculate the number of grams of calcium carbonate that will react with 100 grams of hydrochloric acid. Ans. 137.24 g.

(3) A gas occupies a volume of 250 liters at a pressure of 745 millimeters and a temperature of $-15°$ C. What volume will it occupy at a pressure of 765 millimeters and a temperature of 20° C? Ans. 276.49 liters.

(4) Define: (*a*) flocculent precipitate; (*b*) amphoteric emulsoids; (*c*) dialysis.

(5) From the reaction between zinc and hydrochloric acid

$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

calculate how many liters of hydrogen may be obtained when 100 grams of zinc is treated with excess HCl. Ans. 34.31 liters.

(6) Calculate the per cent of water in Epsom salt, $MgSO_4 \cdot 7H_2O$. Ans. 51.16%.

in the form of a proportion the two equal ratios, 6 : 9 and 10 : 15, either one of the following forms may be employed:

$$6 : 9 = 10 : 15 \tag{1}$$

$$\frac{6}{9} = \frac{10}{15} \tag{2}$$

3. The above proportion may be read in two ways: *6 is to 9 as 10 is to 15*; or *the ratio of 6 to 9 equals the ratio of 10 to 15.* Either way may be used, but the latter is recommended.

4. The numbers forming a proportion are called *terms*, and they are numbered consecutively from left to right, thus:

$$\overset{\textit{first}}{6} : \overset{\textit{second}}{9} = \overset{\textit{third}}{10} : \overset{\textit{fourth}}{15}$$

In any proportion, the ratio of the first term to the second term equals the ratio of the third term to the fourth term.

The first and fourth terms of a proportion are called the *extremes*, and the second and third terms, the *means*. Thus, in the foregoing proportion, 6 and 15 are the extremes and 9 and 10 are the means.

5. The correctness of a proportion may be tested by applying the following rule:

Rule.—*In any proportion, the product of the extremes equals the product of the means.*

The proportion, $6 : 9 = 10 : 15$, is correct, since the product of the extremes, 6×15, equals the product of the means 9×10, both products being 90.

If the proportion is written in the fractional form, as $\frac{6}{9} = \frac{10}{15}$, the term must be multiplied in the manner indicated by the diagonal lines, as follows: $\frac{6}{9} \times \frac{10}{15}$. Or, $6 \times 15 = 9 \times 10$. In either case, the result is the same.

6. Problems in Proportion.—The problem that most frequently occurs in proportion is to find one of the terms when the other three terms are given. Suppose the ratio 6 : 13 is

SCIENCE INSTRUCTING INDUSTRY

87760